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E. J. STONE, M.A., F.R.S., Vice-President, in the Chair.

John Harvey Jones, Fairview Villa, Coburg Road, Montpelier, Bristol ;

William Henry Maw, 18 Addison Road, Kensington, W.; and

Albert Taylor, Hurstside, West Molesey, Surrey ;

were balloted for and duly elected Fellows of the Society.

The following candidates were proposed as Fellows of the Society, the name of the proposer from personal knowledge being appended :—

Wm. Henry Fisher Alexander, B.A., 26 Bousfield Road, St. Catherine's Park, S.E. (proposed by J. A. Barringer) ;

John Cockburn, New Club, Edinburgh (proposed by H. H. Turner) ;

Thomas Keig, Prospect Hill, Douglas, Isle of Man (proposed by Isaac Roberts) ;

Arthur Courtauld Willoughby Lowe, B.A., Gosfield Hall, Halstead, Essex, and 76 Lancaster Gate, Hyde Park, W. (proposed by E. J. Lowe) ;

Arthur B. P. Mee, Llanelly, Carmarthenshire (proposed by George Calver) ;

Captain A. T. Miller, R.N., H.M.S. *Conway*, Birkenhead (proposed by Charles Barton) ;

Kenneth James Tarrant, Letchford House, Hatch End, Pinner (proposed by Arthur Cottam).

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*On the Retrogradation of the Plane of Saturn's Ring and of those of his Satellites whose Orbits coincide with that Plane.* By Professor J. A. C. Oudemans.

Being occupied—in behalf of the second volume of the fourth edition of Kaiser's *Sterrenhemel*—with a discussion of the elements of the satellites and the ring of *Saturn*, I was struck by the following circumstance.

As is generally known, Bessel occupied himself at three different epochs with a research on the apparent diameter and the position of the ring of *Saturn*, 1° in 1812, *Königsberger Archiv für Naturwissenschaften und Mathematik*, 1812, 1r Band, p. 113; 2° in 1818, *Berl. Jahrbuch*, 1829, p. 175; and 3° in 1830–35, *Astronomische Nachrichten*, vol. xii. p. 153. These three papers\* have been reproduced by Engelmann in his edition of Bessel's *Abhandlungen*, vol. i. pp. 110, 319 and 150 respectively.

In his first paper Bessel determined the inclination of the ring, using his measures both of the major and of the minor axis, made at a time when it was widely open, in Schröter's observatory at Lilienthal, by the method of projections. The longitude of the node was found by discussing the observations of disappearance and reappearance of *Saturn's* ring, made by several astronomers from 1714 to 1803.

If there were no retrogradation of the ring, the yearly increase of the node's longitude should necessarily have been put  $= 50''\cdot 2$ , but Bessel found this increase to be only  $40''\cdot 57$ , admitting thus a retrogradation of about  $9''\cdot 6$ ; he did not distinctly pronounce himself on what manner this retrogradation is found, but from the connection between the different parts of the paper I think we must conclude that, as in his third paper, it was introduced as an unknown quantity into the equations formed by the disappearances and reappearances of the ring.

In his second paper Bessel gives the measures of the inclination of the ring, made in 1818 with very moderate means; in fact, the instrument employed was an equatorial of Dollond, provided with a telescope of 16 inches (focal distance); in the field of the strongest eyepiece there was stretched a single wire, and by moving the instrumental arc of this instrument till this wire was parallel to the major axis of the ring, and by reading the latitude-arc and the noniuses, the inclination of the ring to the vertical was found. It is not surprising that these observa-

\* Professor E. S. Holden, comparing his and Professor Asaph Hall's determinations of the inclination of *Saturn's* ring, made at Washington during the years 1877, 1878, and 1879, with Bessel's (*Monthly Notices*, April 1882), overlooks the last and most renowned determination, and cites only that of 1818. This explains the large probable error of a single observation of Bessel's, viz.  $24'\cdot 1$ , whereas Hall's is found to be  $8'\cdot 6$ , and Holden's  $10'\cdot 3$ .

tions (the only one cited by Professor Holden) possess the relatively high probable error of  $\pm 24'.1$ .

Bessel became possessed of a heliometer in March 1829, and in his third paper he follows the same method as in his first; 131 measures, made with the heliometer, of the inclination of the major axis of the ring, taken at an epoch when it was very narrow, gave him 67 equations between  $\delta n$ ,  $\delta i$  and  $m$ , where

$\delta n$  is the correction of the adopted node,  $167^\circ 21' 0''$ , for 1833;

$\delta i$ , the correction of the adopted inclination,  $28^\circ 9' 30''$ , for 1833; and

$m$ , the annual variation of the node of the ring's plane on that of the planet's orbit;

and the observed disappearances and reappearances of the ring gave between the same unknown quantities 20 equations, out of which only 15 have regard to observations made on two successive days, viz. before and after the phenomenon, and these equations alone were taken into account.

The 67 equations of the first order, of weights varying from 1 to 4, have all small coefficients of  $\delta n$  and  $m$ , but a negative coefficient of  $\delta i$  not much differing from unity, so they have been combined according to their weight, and gave the following mean equation:

$$(131 \text{ observations}) \dots 0 = 65''.2 + 0.0452 \delta n - 0.9647 \delta i + 0.25 m.$$

The fifteen equations of the second order have all nearly the same positive or negative coefficient of  $\delta n$ , viz. from 0.4700 to 0.4710. The coefficients of  $\delta i$  have all their signs contrary to that of  $\delta n$ , and a value of from 0.0657 to 0.0894. Excepting the two last equations given by the observations of the disappearance on April 26 and the reappearance on June 13, 1833 (i.e. after the epoch 1833.0), the coefficient of  $m$  has the same sign as that of  $\delta n$ , but it diminishes from 53.28 (1714, October 15) to almost naught. (N.B. 0.47 is the sine of the inclination  $28^\circ 9' 30''$  and the coefficient of  $m$  is = the coefficient of  $\delta n$  multiplied by the number of years before the epoch.)

Believing (probably after the result of his former investigation) that the value of  $m$  was nearly  $= 10''$ , Bessel introduced the new unknown quantity  $m' = m - 10$ , but afterwards he returned to  $m$ , and accordingly we will employ this letter only. Treating the fifteen equations of the second order by the method of least squares, Bessel found:

$$0 = -151.59 + 3.3205 \delta n - 0.5486 \delta i + 167.949 m$$

$$0 = -23577 + 167.949 \delta n - 27.317 \delta i + 12635.3 m$$

Combining these equations with the one given above,\* Bessel found:

\* This equation is repeated in Bessel's paper, in the *Astronomische Nachrichten*, in column 167, but with the wrong sign of the term containing  $\delta i$  ( $+0.9647 \delta i$ , instead of  $-$ ), and this error is repeated in the reprint in Engelmann's edition of the *Memoirs of Bessel*.

$$\left. \begin{aligned} \delta i &= + 63'', 1 \\ \delta n &= - 137'', 9 \\ m &= + 3'', 848 \end{aligned} \right\} *$$

and as

$$n = 167^\circ 21' 0'' + \delta n + (50''.125 - 0.95206 m) (T - 1833)$$

$$i = 28^\circ 9' 30'' + \delta i - (0''.487 - 0.03553 m) (T - 1833)$$

he gives his result in the following shape :

$$n = 166^\circ 53' 8''.9 + 46''.462 (T - 1800)$$

$$i = 28^\circ 10' 44''.7 - 0''.350 (T - 1800)$$

in which they are generally adopted. The astronomical almanacs start from these formulæ to calculate annually the elements of *Saturn's* ring, &c. Even those astronomers who make researches upon the orbits of the satellites, so far as they assume these orbits to coincide with the plane of the ring, accept them as established facts.

It appears to me that the result, published by Bessel, is not so accurate and trustworthy as it seems to be. The coefficient  $46''.462$  is given to a thousandth of a second, but I have a strong doubt whether even the units are to be depended upon.†

Bessel has not added any discussion of the probable errors of his results, though this was not very troublesome. The equations of the first order stand apart, they can only serve to determine  $\delta n$ ; after having substituted into them the values of the unknown quantities, there remain sixty-seven errors. Squaring them and multiplying each square by the weight, the result is ( $m$  being the mean error):—

$$(67 - 1) m^2 = 22458$$

$$m^2 = 340.3$$

$$m = \pm 18'.45 \quad (0.6745 m = \pm 12'.44).$$

The equations of the second order that served to determine  $\delta n$  and  $m$  were only fifteen in number. Since the laws of the oscillations of the rings are unknown, we are obliged, if we wish to form a judgment on the uncertainty of the result, to consider the remaining differences as errors of observation. So we obtain for these equations :

$$(15 - 2) m^2 = 253.07$$

$$m^2 = 19.47$$

$$m = \pm 4'.41$$

\* This solution is not exact. The true values are given below.

† It seems to me to be an abuse of the method of least squares to publish a result with more than one figure than can be accounted for, and especially, as was here the case, if the mean or probable error is not added. *One* figure may be admitted, to indicate if the last figure but one be full or not full. Encke's famous value *in four decimals!* of the Sun's parallax,  $8''.5776$ , and still more his second improved one *IN FIVE DECIMALS!!*  $8''.57116$ , *whereas the first decimal was wrong*, ought to be a warning example to every astronomical calculator.

Adding now the mean and probable errors to the values of the unknowns as we found them, we have:

|            | Equation of the order. | Weight. | Value found. |          | Mean Error. | Probable Error. |
|------------|------------------------|---------|--------------|----------|-------------|-----------------|
| $\delta i$ | 1st                    | 131     | + 62''·1     | = + 1' 0 | ± 1'·6      | ± 1'·1          |
| $\delta n$ | 2nd                    | 1·08    | - 138''·1    | = - 2'·3 | ± 4'·2      | ± 2'·9          |
| $m$        | 2nd                    | 4139·6  | + 3''·836    |          | ± 4''·1     | ± 2''·8         |

Thus we see that the value found by Bessel for  $m$ , i.e. the yearly retrogradation of *Saturn's* ring, with respect to his orbit, though larger than its probable error, is at all events smaller than its mean error.

Let us consider now the theoretical value of this retrogradation. Laplace has already, in his most splendid *Mécanique Céleste*, treated the subject, and though we are now able to substitute better values for the constants he employs, his results are still of force. In the Fifth Book he proves that those satellites whose orbits lie in the plane of the planet's equator (i.e. all except *Iapetus*) are kept in that plane by the rotating and elliptic planet, and as the ring may be considered as an aggregation of satellites it is in the same case. And he closes that book by the remark, that *Saturn's* equator, in its very slow motion, caused by the action of the Sun and *Iapetus*, carries with it the planes of the rings and of the satellites.

In § 37 of the Eighth Book he finds for the solar precession of Saturn

$$0\cdot878 \text{ centesimal seconds} = 0''\cdot2845,$$

and for that due to the action of *Iapetus*

$$6195 \text{ centesimal seconds} \times L = 2007''\cdot2 L,$$

$L$  being the mass of this satellite, that of *Saturn* being taken as unity. By the fact that there has not been found any inclination of *Titan's* orbit to the ring's plane, nor the existence of a fixed plane, making an angle with the ring's plane, and with which *Titan's* orbit makes a constant angle, whereas the line of the nodes has a retrograde motion, Laplace proves that the mass of *Iapetus* is very small—smaller, indeed, than  $\frac{1}{200}$ th of that of *Saturn*. We may go farther, thanks to the beautiful photometric investigations of Professor Pickering. Taking as an approximation, according to Table LII. on p. 269 of the Ninth Volume of the "Annals of the Harvard College Observatory," the equivalent mean diameter of *Iapetus* =  $0\cdot0069 \times$  that of *Saturn*, and

the ellipticity of that planet =  $\frac{1}{9\cdot2}$ , we have:

$$\begin{aligned} \text{Volume of } Iapetus &= \frac{9\cdot2}{8\cdot2} \cdot 0\cdot0069^3 \text{ volume of } Saturn \\ &= 0\cdot00000036837 \text{ volume of } Saturn \\ &= \frac{1}{2713000} \text{ volume of } Saturn. \end{aligned}$$

Knowing nothing about the density of this satellite, the safest way is to take it equal to that of the planet, then the satellite's mass is expressed by the same fraction, that of *Saturn* being taken as unity. And so we find for the precession of *Saturn's* equator due to *Iapetus* the approximate value of  $0''.00074$ .

I have myself made the calculation of these precessions in the following way:—Supposing the densities of the ellipsoidal layers in the Earth and in *Saturn* to follow the same law, and putting

|                                                            | For the Earth. |     | For <i>Saturn</i> . |          |
|------------------------------------------------------------|----------------|-----|---------------------|----------|
| The solar precession                                       | ...            | ... | $\psi_e$            | $\psi_s$ |
| The time of the rotation on the axis                       | ...            | ... | $d_e$               | $d_s$    |
| The excentricity of the meridian                           | ...            | ... | $e_e$               | $e_s$    |
| The inclination of the equator upon the plane of the orbit | ...            | ... | $i_e$               | $i_s$    |
| The mean distance from the Sun                             | ...            | ... | $a_e$               | $a_s$    |
| The angle of excentricity of the orbit                     | ...            | ... | $\phi_e$            | $\phi_s$ |

we have:

$$\psi_e : \psi_s = \frac{d_e e_e^2 \cos i_e}{a_e^3 \cos^3 \phi_e} \cdot \frac{d_s e_s^2 \cos i_s}{a_s^3 \cos^3 \phi_s}$$

Taking

$$\begin{aligned} d_e &= 1436^m & d_s &= 615^m \\ e_e^2 &= \frac{1}{145} & e_s^2 &= \frac{9 \cdot 2^2 - 8 \cdot 2^2}{9 \cdot 2^2} = \frac{17 \cdot 4}{84 \cdot 64} \\ i_e &= 23^\circ 27' \cdot 3 & i_s &= 26^\circ 49' \cdot 5 \\ a_e &= 1 & a_s &= 9 \cdot 53885 \\ \phi_e &= 0^\circ 57' \cdot 65 & \phi_s &= 3^\circ 12' \cdot 9 \\ \psi_e &= 15'' \cdot 82^* \end{aligned}$$

we find :

$$\psi_s = 0''.2273.$$

To compare further the action of the Sun  $\psi_s$  to that of *Iapetus*  $\psi_j$ , we have:

$$\psi_s : \psi_j = \frac{\text{Mass of Sun} \times \cos i_s}{a_s^3 \cos^3 \phi_s} \cdot \frac{\text{Mass of } Iapetus \times \cos i}{a_j^3 \cos^3 \phi_j}.$$

\* There is an uncertainty of a little more than  $0''.1$  in this quantity. Adopting the lunisolar precession  $= 50''.35$ , and the Moon's mass  $= \frac{1}{81 \cdot 5}$ , I get  $15''.93$ . Nyren takes the lunisolar precession for 1850  $= 50 \cdot 3164$ , which value he deduced from the catalogues of Weisse and of Schjellerup (*Bestimmung der Nutation der Erdochse*, St. Petersburg, 1872, p. 54). From his nutation-constant I find the Moon's mass  $= \frac{1}{80 \cdot 5}$  and the solar precession  $15''.79$ ; but if I take the lunisolar precession to be  $= 50''.35$ , more conform to Ludwig Struve's last determination, we get  $15''.82$  for the solar only, as we have adopted above.

I signifying the inclination of the orbit of *Iapetus* upon the equator of *Saturn* =  $13^{\circ} 28'$  :

$$a_j, \text{ the semi-axis major of } Iapetus's \text{ orbit} = a_s \sin 515'' \cdot 5$$

$$\phi_j, \text{ the angle of excentricity of } Iapetus's \text{ orbit} = 1^{\circ} 35' \cdot 6.$$

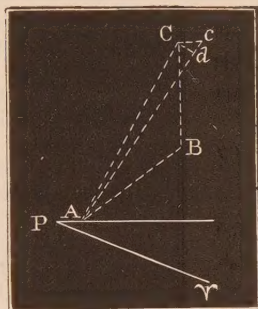
The result is :

$$\psi_j = 0'' \cdot 001665$$

But this regards a turning of the pole of *Saturn's* equator around the pole of *Iapetus's* orbit, whereas we must find the turning of the same pole around the pole of *Saturn's* orbit.

Let, in the accompanying diagram,

- A be the pole of *Saturn's* orbit,
- B that of *Iapetus's* orbit,
- C that of *Saturn's* equator,
- P that of the ecliptic,
- $\gamma$  the vernal equinox.



We have for 1850 :

$$\gamma PA = 22^{\circ} 21'$$

$$PA = 2^{\circ} 30'$$

$$\gamma PB = 52^{\circ} 28' \text{ and } APB = 30^{\circ} 7'$$

$$PB = 18^{\circ} 39'$$

$$\gamma PC = 77^{\circ} 36' \text{ and } APC = 55^{\circ} 15'$$

$$PC = 28^{\circ} 10'$$

And herewith we find :

$$AB = 16^{\circ} 32'$$

$$AC = 26^{\circ} 48' \cdot 8$$

$$PAB = 145^{\circ} 40' \cdot 5$$

$$PAC = 120^{\circ} 42' \cdot 4$$

$$\therefore CAB = 24^{\circ} 58' \cdot 1$$

In the spherical triangle ABC, AB, AC and the angle BAC being known, we find :

$$BC = 13^{\circ} 36'$$

$$\text{Angle } C = 30^{\circ} 43'$$

The turning around B takes place in the directions Cc, perpendicular to BC, but we want to know the turning around A, so letting fall the perpendicular Cd we have :

$$C c = \psi_j \sin B C$$

$$C d = C c \cos C$$

$$C A d = \frac{C d}{\sin A C} = \frac{\sin B C \cos C}{\sin A C} \cdot \psi_j$$

$$= 0'' \cdot 000746$$

in full accordance with Laplace. Adding the solar precession  $0'' \cdot 2273$ , the *Iapeti-solar* precession becomes  $0'' \cdot 2280$ .

There remains now to consider the action of the ring, retrograding itself by the Sun's attraction, on the planet.

The ring may be considered as an aggregation of satellites. Taking the mean semi-diameter of the ring at *Saturn's* mean distance  $= 16'' \cdot 75$ , we find, by comparison with the satellites, the time of rotation  $= 0 \cdot 4647$  days  $= t$ .

The same element of *Saturn* is  $10759$  days  $= T$ .

A fair approximation of the time of retrogradation of the nodes of such a satellite is (Möbius, *Mechanik des Himmels*, p. 223):

$$\frac{4}{3} \cdot \frac{T^2}{t} \text{ days} = 322200000 \text{ days}$$

$$= 909500 \text{ years.}$$

So that the yearly retrogradation of the ring's node, if the planet were not elliptical, should be

$$1'' \cdot 425.$$

If the ring were solidly attached to the planet it would draw it along, and the result would be a retrogradation between  $0'' \cdot 228$  and  $1'' \cdot 425$ , easily to be determined, taking into account the proportion of the different moments of inertia.

Calculating only the moments of inertia with regard to the rotatory axis, we find

$$\text{Mom. of inertia of planet} = \text{mass of planet} \times \frac{2}{5} a^2$$

$$,, \quad ,, \quad \text{of the ring} = \text{mass of the ring} \times \frac{1}{2} (r^2 + r'^2).$$

Taking

$$r' = 19'' \cdot 75, \text{ the outer radius of the ring,}$$

$$r = 13'' \cdot 75, \text{ the inner radius of the ring,}$$

$$a = 8'' \cdot 65, \text{ the radius of } \textit{Saturn's} \text{ equator}$$

(the final values, which we arrived at after careful discussion) we

find, if the mass of the ring  $= \frac{1}{\mu} \times$  the mass of *Saturn* :

$$\frac{\text{Moment of inertia of ring}}{\text{Moment of inertia of } \textit{Saturn}} = \frac{9 \ 688}{\mu}.$$

The fraction  $\frac{1}{\mu}$  is yet very uncertain. Bessel, disregarding the ellipticity of the planet, made it  $\frac{1}{118}$ , but was, of course, aware that this value was too great. Tisserand, to explain a very vague expression of Captain Jacob: "The apsides (of *Mimas*) seem to have made nearly a semi-revolution in the course of a year," and having found by theory that by the planet's ellipticity alone the line of *Mimas's* apsides has a yearly motion of  $349^\circ$ , supposes that motion to have been (between January 1857 and January 1858, the epochs of Jacob's observations)  $1\frac{1}{2}$  revolution, and in that supposition

$$\text{"On trouverait } \frac{m}{M} = \frac{1}{620} \text{"}$$

but, considering that the observations of Professor Asaph Hall at Washington, made with much more powerful means than Jacob's, do not reveal an ellipticity of the orbit of *Mimas*, I believe this value cannot be properly named a result, especially as Jacob himself acknowledges (*Memoirs Royal Astronomical Society*, vol. xxviii. p. 69) "The observations registered of *Enceladus* and *Mimas* are in general little better than *estimates* of the direction," and as an error in the position-angle is enlarged when reduced to an error in the satellite's kronocentric longitude, the observations of these satellites being taken only in the elongations.

The latest valuation of the ring's mass is that of Hermann Struve,\* who, consulting the motions of the apsides, both the direct one of *Titan* and the retrograde one of *Hyperion*, and adopting the best available measures of *Saturn's* equatorial and polar diameters, treats the problem as leading to two equations with two unknowns, viz. the mass of *Titan* (which is found  $\frac{1}{4678}$ ), and the mass of the ring, for which is found the superior limit of  $\frac{1}{314}$ .

Adopting this value, we find for the superior limit of the moments of inertia of the ring and the planet about  $\frac{1}{32.4}$ , and so the common retrogradation of the ring and the planet could not rise higher than

$$0''\cdot228 + \frac{1}{33.4} \times 1''\cdot197 = 0''\cdot264.$$

Now the ring is not solidly attached to the planet, but as the spheroidic planet keeps the ring in the plane of the equator, the

\* In his beautiful memoir: *Beobachtungen der Saturnstrabanten*, 1<sup>e</sup> Abtheilung, 'Beobachtungen am 15-zölligen Refractor.' Supplément I. aux *Observations de Poulkova*, St. Pétersbourg, 1888.

effect is likely to be not much less, and so I believe that, taking a round number,

$$0''\cdot25,$$

is a fair approximation to the precessional retrogradation of the ring and planet together.

I return to Bessel's solution. Bessel gave his results in a form as if the mean epoch of the observations were 1800, but, on the contrary, it was 1833 $\cdot$ 0 for his own determinations of the inclination, and 1780 for the determination of the node. The consequence is that if we do not adopt the retrogradation of the node found by him (3'' $\cdot$ 848) we shall find another longitude of it for 1800, but the same for 1780 and this one with the maximum of weight. Indeed, we find for 1780

| Weight.       | Mean error of $\delta n$ . | Probable error. |
|---------------|----------------------------|-----------------|
| 3 $\cdot$ 295 | $\pm 2''\cdot4$            | $\pm 1''\cdot6$ |

The yearly increase of the longitude of the ring's node with the ecliptic becomes now :

$$50''\cdot125 - 0\cdot95206 m = 49''\cdot89$$

And so there follows from our considerations that the results of Bessel's investigation ought to be written in the following way :

|                                      | Probable Error. | Yearly Variation.               |
|--------------------------------------|-----------------|---------------------------------|
| For 1780 : $n = 166^\circ 37'\cdot7$ | $\pm 1''\cdot6$ | $+ 49''\cdot89 = + 0'\cdot8315$ |
| For 1833 : $i = 28^\circ 10'\cdot7$  | $\pm 1''\cdot1$ | $- 0\cdot48 = - 0'\cdot0080$    |

or in other words :

$$\begin{aligned} n &= 166^\circ 37'\cdot7 + 0'\cdot8315 (T - 1780), \\ i &= 28^\circ 10'\cdot7 - 0'\cdot0080 (T - 1833). \end{aligned}$$

The difference between my result and Bessel's is not so very small ; it is 3'' $\cdot$ 6 per annum. Bessel's mean year (not given by him) was 1780 ; consequently we have now the effect of 109 years, and  $109 \times 3''\cdot6 = 392'' = 6'\cdot5$ . But as *Saturn* is at a distance of nearly 10 unities, a change of direction of the node-line of 6' $\cdot$ 5 corresponds in the neighbourhood of the Sun to about 1 $^\circ$  of the circumference of the Earth's orbit. Thus the difference in a disappearance or reappearance when the Earth passes the plane will be *one day at least*, but generally more ; and when the *Sun* passes the plane, it is at least three days, owing to the so much slower motion of *Saturn*.

Since 1835 we have had three epochs of disappearances and reappearances of the ring, viz. 1848-49, 1861-62, and 1878, and the next to come is 1891. In the following table I have collected the times of disappearance and reappearance according to Bessel, and I have added the correction, necessary if our formula be adopted.

|      | Authority.    | Epoch according to Bessel. |                                         | Correction.                       | Resulting epoch.                       |   |
|------|---------------|----------------------------|-----------------------------------------|-----------------------------------|----------------------------------------|---|
| 1848 | Disappearance | B. J.                      | April 21 <sup>h</sup> 21 <sup>h</sup> 4 | -0 <sup>h</sup> 14 <sup>h</sup> 8 | April 21 <sup>h</sup> 6 <sup>h</sup> 6 | ♂ |
|      | Reappearance  | "                          | Sept. 3 3 <sup>h</sup> 3                | +1 23 <sup>h</sup> 0              | Sept. 5 2 <sup>h</sup> 3               | ⊙ |
|      | Disappearance | "                          | " 12 12 <sup>h</sup> 8                  | +0 22 <sup>h</sup> 2              | " 13 11 <sup>h</sup> 0                 | ♂ |
| 1849 | Reappearance  | "                          | Jan. 19 8 <sup>h</sup> 3                | -0 15 <sup>h</sup> 4              | Jan. 18 16 <sup>h</sup> 9              | ♂ |
| 1861 | Disappearance | "                          | Nov. 23 1 <sup>h</sup> 05               | +1 7 <sup>h</sup> 6               | Nov. 24 8 <sup>h</sup> 65              | ♂ |
| 1862 | Reappearance  | "                          | Jan. 31 19 <sup>h</sup> 5               | -1 9 <sup>h</sup> 6               | Jan. 30 9 <sup>h</sup> 9               | ♂ |
|      | Disappearance | "                          | May 18 2 <sup>h</sup> 8                 | +2 7 <sup>h</sup> 1               | May 20 9 <sup>h</sup> 9                | ⊙ |
|      | Reappearance  | "                          | Aug. 12 20 <sup>h</sup> 2               | +0 16 <sup>h</sup> 4              | Aug. 13 12 <sup>h</sup> 6              | ♂ |
| 1878 | Disappearance | N. A.*                     | Feb. 6 11                               | +2 20                             | Feb. 9 7                               | ⊙ |
|      | Reappearance  | "                          | Mar. 1 4                                | -0 18 <sup>h</sup> 6              | Mar. 0 9 <sup>h</sup> 4                | ♂ |
| 1891 | Disappearance | "                          | Sept. 22 18 <sup>h</sup> 9              | +0 21 <sup>h</sup> 0              | Sept. 23 15 <sup>h</sup> 9             | ♂ |
|      | Reappearance  | "                          | Oct. 30 10 <sup>h</sup> 9               | +3 6 <sup>h</sup> 0               | Nov. 2 16 <sup>h</sup> 9               | ⊙ |

It is not yet possible to decide if the epochs of the last column satisfy better than Bessel's. I found the following observations of the disappearances and reappearances :

1848. First disappearance. (A.R. ♀ - A.R. ⊙ = 21<sup>h</sup> 5.) No observations found.

First reappearance. (♀ - ⊙ = 12<sup>h</sup> 8), Bond. Between August 31, 1878, and September 3<sup>h</sup> 80, G.M.T. (*Monthly Notices*, vol. x. p. 17).

September 3, Schwabe: "no trace" (*Astronomische Nachrichten*, 665).

September 4, 9<sup>h</sup> 5, Schwabe: sees the ring (6 f. telescope).

Julius Schmidt, at Bonn, sees the ring September 3 (heliometer and 5 f. telescope). (*Astronomische Nachrichten*, 648).

Busch, at Königsberg, September 5 (4-inch Plössl.), after cloudy weather (*Astronomische Nachrichten*, 658).

Galle, at Berlin, September 5, "zuerst im Refractor" (*Astronomische Nachrichten*, 647).

Dawes, September 1. Power 163. No trace of the ring (*Monthly Notices*, vol. x. p. 47).

September 2, 11<sup>h</sup> G.M.T. Power 163. The ring is visible as an excessively narrow line of nearly the same colour as the planet.

\* In the *Berliner Jahrbuch* of 1878, the elements of the ring of Saturn were omitted.

Second disappearance ( $\text{h} - \odot = 12^{\text{h}}.1$ ), Bond : between September 12.80 and 13.62 G.M.T. (l.c.) Schmidt sees the ring September 11, but saw it not September 14 at 8<sup>h</sup> (*Astronomische Nachrichten*, 850). Busch : a trace September 13, no ring September 15 (*Astronomische Nachrichten*, 658). Schwabe : September 12 only the western ansæ, the 13th no trace (*Astronomische Nachrichten*, 665).

Second reappearance 1849, January ( $\text{h} - \odot = 3^{\text{h}}.4$ ). Bond : between January 18.47 and 19.43 (l.c.). Schwabe : January 19 not visible, January 21 a thin line (*Astronomische Nachrichten*, 667). Schmidt : January 18 not, 21 well visible (*Astronomische Nachrichten*, 650).

1861. First disappearance ( $\text{h} - \odot = 19^{\text{h}}.6$ ). Secchi : the 23rd of November only a feeble line of light ("un faible trait de lumière"). (*Astronomische Nachrichten*, 1341.)

1862. First reappearance ( $\text{h} - \odot = 14^{\text{h}}.6$ ). Schwabe sees the ring (after long cloudy weather ? ?) for the first time 1862, February 7 (*Astronomische Nachrichten*, 1384).

Second disappearance ( $\text{h} - \odot = 7^{\text{h}}.5$ ). Dawes, May 17 : Scarcely ; no shadow of ring ! (*Monthly Notices*, vol. xxii. p. 297.) Huggins saw the ring May 17, 18, and 19, and even 20, when the ansæ appeared "of a beautiful dark colour, scarcely distinguishable from the dark blue of the sky, which contrasted strongly with the yellow light of the ball."

Carpenter at Greenwich and O. Struve (at Pulkowa ?) saw the ring very well May 19, but also May 20, 25, and June 1 ; so I suppose it was the border of the ring that they saw, like also Huggins on May 20.

1878.  $\text{h} - \odot = 1^{\text{h}}.8$  at disappearance.  
 $= 0^{\text{h}}.9$  at reappearance.

No observations found.

1891.  $\text{h} - \odot = 23^{\text{h}}.5$  at disappearance.  
 $= 21^{\text{h}}.4$  at reappearance.

We see that in 1891 it will be impossible to observe the disappearance of the ring, but there is a chance left for the reappearance ; the observations, however, must then be made before sunrise.

*Utrecht : 1888, December 12.*

*Photographs of the Nebulæ M 31, h 44, and h 51 Andromedæ, and M 27 Vulpeculæ. By Isaac Roberts.**Nebulæ M 31, h 44, and h 51 Andromedæ.*

The photograph\* which accompanies these notes was taken on October 1 last, and it throws a very different light to that hitherto seen by astronomers upon the constitution of the great nebula, and we shall not exaggerate if we assert that it is now for the first time seen in an intelligible form.

No verbal description can add much to the information which the eye at a glance sees on the photograph, and those who accept the nebular hypothesis will be tempted to appeal to the constitution of this nebula for confirmation, if not for demonstration, of the hypothesis. Here we (apparently) see a new solar system in process of condensation from a nebula—the central sun is now seen in the midst of nebulous matter which in time will be either absorbed or further separated into rings. The farthest boundaries of the nebula have already separated into rings more or less symmetrical with the nucleus, and present a general resemblance to the rings of *Saturn*.

The two nebulae *h 44* and *h 51* seem as though they were already undergoing their transformation into planets. But I must refrain from further running riot with the imagination and draw attention to some points shown upon the photograph, premising that we have now the means of keeping a strict watch upon many of the structural details of the nebula which in time may enable astronomers to arrive at a demonstration of the nebular hypothesis.

It will be observed that the nebula *h 44* is shown on Bond's drawing with its major axis forming an angle of about  $45^\circ$  with a line joining its centre with the centre of *h 51*, whereas the photograph shows the axis to be pointed much more directly towards that nebula—the angle being less than  $20^\circ$ .

The difference is so obvious that we may reasonably suspect that it is not wholly due to error in charting but is indicative of a change in the direction of the axis since the year 1847, and some confirmation of this supposition is also given by comparison of the distances between the centres of the two nebulae and the nucleus of the great nebula.

On Bond's chart the distance ratio of *h 51* and *h 44* with the nucleus is as 32 to 54, but on the photograph it is as 36 to 54, thus showing a large discrepancy.

*M 27 Vulpeculæ.*

The accompanying photograph of this nebula was taken on October 3 last, and shows more of the structure than the one with shorter exposure which was presented to the Society last year. It would be difficult to recognise in the photograph any resemblance to a dumb-bell, and only in general outline does it resemble the best drawings published of it.

\* The photographs are deposited in the Library.

*Height of a Leonid Fireball.* By W. F. Denning.

A large meteor observed under nearly similar circumstances to those attending the Perseid fireball of August 13 last (*Monthly Notices*, 1888, November, p. 19) was recorded at Bristol and Sunderland on the night of November 13, at 17<sup>h</sup> 19<sup>m</sup>.

The observations were as under :—

*Bristol.*—The writer recorded twenty-nine meteors between the hours of 15<sup>h</sup> 30<sup>m</sup> and 18<sup>h</sup> (1888, November 13), and amongst this number there were seventeen which, by their directions and other features of appearance, conformed with the well-known stream of Leonids. The radiant point was in the usual position at 149° + 22°, and three of the meteors were unusually large with apparent paths as follows :

|         |       | Mag.     | From      | To        | Appearance.                  |
|---------|-------|----------|-----------|-----------|------------------------------|
| 1888.   | h m   |          |           |           |                              |
| Nov. 13 | 16 41 | 4        | 166 + 34  | 172 + 37½ | V. swift, b. streak 5°       |
|         | 16 55 | Fireball | 125½ - 22 | 121 - 30½ | V. b. flash, swift, stk. 10° |
|         | 17 19 | 4        | 252 + 33½ | 257½ + 31 | Swift, streak 5°             |

The fireball at 16<sup>h</sup> 55<sup>m</sup> was a splendid object, though it appeared very low in the southern sky. The meteor at 17<sup>h</sup> 19<sup>m</sup> was also of considerable size, but its apparent brilliancy must have been greatly subdued by its situation in the mist immediately contiguous to the N.E. horizon. It appeared slightly N. of  $\epsilon$  *Herculis* and its line of flight was sensibly parallel with  $\epsilon$  and  $\zeta$  *Herculis*.

*Sunderland*—Mr. T. W. Backhouse was watching the progress of the Leonid shower on the same night. At 17<sup>h</sup> 19<sup>m</sup> he became suddenly aware of a bright flash and, a few seconds later, discovered an unusually intense meteor-streak lying amongst the stars of *Boötes* and about 5° below *Arcturus*. It was estimated as 4° long at first, and proved very durable, for it remained in sight during a period of nine minutes, during which it exhibited some alterations both in its shape and position. Mr. Backhouse was careful to notice the place of the streak directly after its first detection, when it extended from 213½° + 16½° to 217¼° + 15°, and he justly surmised it had been left by a Leonid fireball.

On comparing the pair of observations at 17<sup>h</sup> 19<sup>m</sup> it becomes obvious they relate to the same body, and that a satisfactory path can be derived from them. The radiant point is shown at 149° + 25° in the northern part of the sickle of *Leo*, which was in azimuth E. 50½° S. at the moment of the meteor's apparition. The heights of the beginning and end points of its path, observed at Bristol, were 65 and 37 miles respectively, and its central position was above a place in the North Sea, in about lat. 55¼° N., long. 3¼° E. The long enduring light streak visible

at Sunderland was nearly 15 miles in length, and the heights of its extremities were 57 and 45 miles. Its mean elevation was

17<sup>h</sup> 19<sup>m</sup>17<sup>h</sup> 22<sup>1</sup>/<sub>4</sub><sup>m</sup>17<sup>h</sup> 28<sup>m</sup>

Streak of fireball, 1888, November 13, observed at Sunderland.

therefore 51 miles, which is but slightly less than that of the streak of the Perseid fireball before adverted to, and which indicated an average height of 53 miles. The length of the meteor's visible course was 34 miles, and its Earth-point was near lat. 55°6 N., long. 3°3 E. The duration of its flight was not estimated, so that its velocity cannot be determined. At Bristol, however, it was described as "swift," and the direct inference is that its motion probably accorded with the usual high rate of speed attributed to the Leonids.

Summarising the results we have:

|                                                   |               |
|---------------------------------------------------|---------------|
| Beginning of meteor (Bristol) ... ..              | 65 miles high |
| "    " light streak (Sunderland) ... ..           | 57 "          |
| End of light streak (Sunderland) ... ..           | 45 "          |
| End of meteor (Bristol) ... ..                    | 37 "          |
| Inclination to mean horizon ... ..                | 57°           |
| Entire length of observed real path (Bristol) ... | 34 miles.     |

The heights do not differ materially from the average of fireballs (*Monthly Notices*, 1888, January, p. 113), though the length of path is decidedly shorter than usual. But the meteor was at a great distance (more than 360 miles) from Bristol, and being

so close upon the horizon the conditions for glimpsing the fainter sections of its track were extremely unfavourable. It is certain that the low-lying vapours combined with the excessive distance in obliterating the streak which remained so persistent at Sunderland. The same effects were produced by similar causes in the case of the Perseid fireball, the streak of which endured at Leeds for three minutes, whereas at Bristol, the distance being greater and altitude of the object much less, it continued to be seen no longer than 40 secs. It will be interesting during future observations to compare the heights of the durable streaks which are so often generated by fireballs, and to further trace the effects of distance and altitude upon their visibility at different stations.

The diagram represents successive views of the streak left by the recent Leonid fireball. This feature had become very faint at 17<sup>h</sup> 28<sup>m</sup> (9 min. after first appearance), when it was just observable with an opera-glass, power 4.

*Bristol: 1888, December 12.*

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*The Great Southern Comet (1887 I). By Dr. H. Oppenheim.*

*(Extract from a letter to Mr. Knobel.)*

Being at present occupied with a determination of the orbit of the great Southern Comet (1887 I), I have examined some observations made at sea by Captain Molony, which appeared in the *Monthly Notices*, vol. xlvii. p. 432.

As altogether only 19 observations of this Comet are known, earlier observations have great importance, as sextant observations have equal value with those of fixed instruments, which give distances to half a degree (*Astronomische Nachrichten*, Band 117, p. 13).

Captain Molony's observations as printed in the *Monthly Notices* appear, however, to be incorrect, as will be seen from the accompanying comparison. Would it be possible for you to make the observer acquainted with this, and inform me as to his reply? \*

The following results are obtained from a comparison of the observations of Comet 1887 in the *Monthly Notices*, vol. xlvii. p. 432 (taking refraction into account) with the elements given in the *Astronomische Nachrichten*, 117, p. 13.

\* Lieut. Baillie, of the Meteorological Office, has kindly compared the observations as printed in the *Monthly Notices* with Capt. Molony's meteorological log, and finds they have been correctly copied, so that the errors must rest with the observer.

1887, Jan. 21.

Measured distance.

Obs.—Com.

R.A.  
 $\Delta\alpha$ Decl.  
 $\Delta\delta$ 

|                          |     |     |     |                  |                  |
|--------------------------|-----|-----|-----|------------------|------------------|
| Canopus— $\alpha$ Crucis | ... | ... | ... | $-3^{\circ} 50'$ | $+0^{\circ} 45'$ |
| Canopus—Rigel            | ... | ... | ... | $+3^{\circ} 0'$  | $+3^{\circ} 4'$  |
| $\alpha$ Crucis—Rigel    | ... | ... | ... | $+0^{\circ} 23'$ | $-0^{\circ} 24'$ |

January 22 :

|                                   |     |     |     |                  |                  |
|-----------------------------------|-----|-----|-----|------------------|------------------|
| Canopus— $\alpha$ Crucis          | ... | ... | ... | $+0^{\circ} 31'$ | $+0^{\circ} 37'$ |
| Canopus— $\alpha$ Arietis         | ... | ... | ... | $+0^{\circ} 11'$ | $+0^{\circ} 30'$ |
| $\alpha$ Arietis— $\alpha$ Crucis | ... | ... | ... | $-0^{\circ} 3'$  | $+0^{\circ} 46'$ |

January 25 :

|                          |     |     |     |                  |                  |
|--------------------------|-----|-----|-----|------------------|------------------|
| Canopus— $\alpha$ Crucis | ... | ... | ... | $+2^{\circ} 27'$ | $+0^{\circ} 41'$ |
| Canopus—Rigel            | ... | ... | ... | $+1^{\circ} 11'$ | $+0^{\circ} 5'$  |
| $\alpha$ Crucis—Rigel    | ... | ... | ... | $+1^{\circ} 28'$ | $+0^{\circ} 51'$ |

From this it appears that the measured distance of the Comet from *Canopus* on January 21 and the measured distance from  $\alpha$  *Crucis* on January 25 are incorrect. This is clear from the following :

Assuming the R.A. and Decl. of the Comet as known, from the ephemerides, and comparing the observed distances of the Comet from the stars, we obtain the following differences between computation and observation :

|              |                  |     |     |     |                  |
|--------------|------------------|-----|-----|-----|------------------|
| January 21 : | Canopus          | ... | ... | ... | $+2^{\circ} 5'$  |
|              | $\alpha$ Crucis  | ... | ... | ... | $-0^{\circ} 13'$ |
|              | Rigel            | ... | ... | ... | $-0^{\circ} 14'$ |
| January 22 : | Canopus          | ... | ... | ... | $+0^{\circ} 23'$ |
|              | $\alpha$ Crucis  | ... | ... | ... | $+0^{\circ} 45'$ |
|              | $\alpha$ Arietis | ... | ... | ... | $-0^{\circ} 18'$ |
| January 25 : | Canopus          | ..  | ... | ... | $-0^{\circ} 19'$ |
|              | $\alpha$ Crucis  | ... | ... | ... | $+1^{\circ} 4'$  |
|              | Rigel            | ... | ... | ... | $-0^{\circ} 40'$ |

Berlin : 1888, Dec. 14.

*Note on the Spectrum of Comet c 1888 (Barnard, September 2).  
By Dr. R. Copeland.*

The spectrum was first examined on November 14. It presented a strange appearance, that at first sight was very puzzling, for instead of the feeble separate bands that usually characterise faint cometary spectra, the spectroscope revealed a rather long, continuous spectrum, extending from W.L. 575<sup>mmm</sup> to W.L. 450<sup>mmm</sup>, brighter in the middle and fading gradually away at both ends. It was, in fact, far more like that of a close globular cluster of stars, or a non-gaseous nebula, than of a mass of self-luminous gas. Owing to the spreading of the light over so great a part of the spectrum, a wide slit was imperatively necessary to permit of distinguishing any special features. Under this condition the spectrum seemed scarcely to differ from that of the zodiacal light or faint daylight, but on close scrutiny a soft, brighter patch of light was recorded at a point that turned out to have a W.L. of 510.5<sup>mmm</sup>, and eventually an extremely feeble increase of light was detected at 476.5<sup>mmm</sup>. These brighter patches probably represent the second and third cometary bands.

On November 26 similar observations were made, but with the addition that some traces of superposed brightness, indicative of the first band, were also distinguished. On December 5 the first and second bands only were measurable, but on the wonderfully clear night of December 8 all three bands were distinctly seen and recognised in and about the comet's nucleus. On each occasion the continuous spectrum already described formed the ground on which the brighter bands were superposed. The following summary shows the results of the measures, which were all made with the Grubb star-spectroscope and a simple prism of 60° angle.

## Summary of Measures.

|                                        | Nov. 14.<br>mm. | No. of<br>Obs. | Nov. 26.<br>mm. | No. of<br>Obs. | Dec. 5.<br>mm. | No. of<br>Obs. | Dec. 8.<br>mm.     | No. of<br>Obs. | Mean.<br>mm. | No. of<br>Obs. |
|----------------------------------------|-----------------|----------------|-----------------|----------------|----------------|----------------|--------------------|----------------|--------------|----------------|
| Spectrum begins ... ..                 | 575             | ...            | 599             | 1              | 572            | 2              | { 588<br>574†      | { 1<br>1       | 580          | 6              |
| 1st band, 1st condensation ... ..      | ...             | ...            | 555.2           | 1              | ...            | ...            | ...                | ...            | 555.2        | 1              |
| " middle of band seen as one           | ...             | ...            | ...             | ...            | 544.2          | 3              | 551.5†             | 3              | 547.8        | 6              |
| " 2nd condensation ... ..              | ...             | ...            | 535.6           | 1              | ...            | ...            | ...                | ...            | 535.6        | 1              |
| 2nd band, limit towards the red ... .. | ...             | ...            | 517.9           | 4              | ...            | ...            | 519.8              | 5              | 519.0        | 9              |
| " brightest part ... ..                | 510.5           | 1              | 515.0*          | 1              | 508.5          | 5              | { 514.0†<br>520.0† | { 3<br>2       | 512.5        | 12             |
| 3rd band ... ..                        | 476.5           | 1              | 478.8           | 1              | ...            | ...            | 472.6†             | 3              | 474.6        | 5              |
| Spectrum ends ... ..                   | 450             | 1              | 453             | 1              | 461            | 2              | 459                | 1              | 455          | 5              |
| Distance of comet from the Sun ... ..  | 2.065           | ...            | 1.998           | ...            | 1.953          | ...            | 1.940              | ...            | ...          | ...            |

\* With a very wide slit, one large bright band was measured at 525.2mm, probably due to the superposition of the first and second bands on the continuous spectrum. Feeble traces of a second band were seen at 464mm.

† On the coma with a wide slit.

‡ Spectrum of nucleus.

Continuous spectrum between these limits.

From these measures it is evident that the bright bands are slowly developing under the continued action of the Sun's rays, and as the perihelion will not be reached until 1889, January 29.9, according to Dr. L. Becker's elements, they will probably become more obvious. Hitherto, however, far from the light being chiefly concentrated in these bands, nearly all the light has been spread out into a continuous spectrum, on which the bands are only seen with close attention. From this it seems probable that the comet shines mainly by reflected light (a question that the polariscope may perhaps decide), to which the action of the Sun on the cometary material is slowly adding the usual bright bands.

*Lord Crawford's Observatory, Dun Echt :*  
1888, December 13.

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## Observations of Comets made at the Oruell Park Observatory in the years 1887-88. By John J. Plummer, M.A.

## Comet V. 1887 (Olters-Brooks.)

| 1887.    | Greenwich<br>Mean Time. | Comet-Star.      |                  | No. of<br>Comps. | Comet's<br>App. R.A. |     |       | Log<br>( $p \times \Delta$ ). | Comet's<br>App. Dec. |     |      | Log<br>( $p \times \Delta$ ). | Red. to App.<br>Place. |      | Comp.<br>Star. |
|----------|-------------------------|------------------|------------------|------------------|----------------------|-----|-------|-------------------------------|----------------------|-----|------|-------------------------------|------------------------|------|----------------|
|          |                         | $\Delta\alpha$ . | $\Delta\delta$ . |                  | $h$                  | $m$ | $s$   |                               | $o$                  | $i$ | $''$ |                               | $s$                    | $''$ |                |
| Sept. 12 | 15 31 57                | +2 59'38         | - 1 12'6         | 8-8              | 9                    | 56  | 4'77  | 9'6129 <sub>n</sub>           | +30                  | 9   | 51'1 | 0'8208                        | +0'08                  | -7'7 | 1              |
| Oct. 10  | 16 31 35                | +1 57'67         | + 8 12'0         | 9-9              | 12                   | 13  | 25'80 | 9'6035 <sub>n</sub>           | +25                  | 23  | 17'2 | 0'8108                        | +0'04                  | -5'3 | 2              |
| 12       | 16 5 31                 | - 1 4'32         | + 3 6'4          | 8-8              | 12                   | 22  | 43'50 | 9'5939 <sub>n</sub>           | +24                  | 47  | 3'3  | 0'8304                        | +0'04                  | -4'8 | 3              |
| 13       | 16 32 1                 | +2 2'32          | + 4 2'7          | 9-9              | 12                   | 27  | 27'38 | 9'6000 <sub>n</sub>           | +24                  | 27  | 42'4 | 0'8146                        | +0'05                  | -4'9 | 4              |
| 17       | 16 55 5                 | +4 13'00         | - 5 51'3         | 8-8              | 12                   | 45  | 44'95 | 9'5974 <sub>n</sub>           | +23                  | 8   | 10'3 | 0'8053                        | +0'07                  | -4'6 | 5              |
| 19       | 16 42 43                | -3 59'56         | - 3 11'3         | 8-8              | 12                   | 54  | 35'76 | 9'5944 <sub>n</sub>           | +22                  | 26  | 49'8 | 0'8156                        | +0'06                  | -3'8 | 6              |
| 21       | 16 30 12                | -2 5'20          | - 5 33'7         | 9-9              | 13                   | 3   | 17'31 | 9'5900 <sub>n</sub>           | +21                  | 44  | 38'3 | 0'8252                        | +0'08                  | -3'7 | 7              |
| 25       | 17 3 12                 | +4 7'98          | - 1 2'4          | 8-7              | 13                   | 20  | 22'38 | 9'5887 <sub>n</sub>           | +20                  | 16  | 38'9 | 0'8111                        | +0'13                  | -3'7 | 8              |
| 28       | 16 42 58                | -2 33'01         | + 0 3'3          | 8-8              | 13                   | 32  | 36'75 | 9'5847 <sub>n</sub>           | +19                  | 9   | 51'7 | 0'8249                        | +0'14                  | -3'2 | 9              |
| Nov. 4   | 17 1 55                 | -2 35'17         | - 4 40'8         | 4-4              | 13                   | 59  | 54'05 | 9'5792 <sub>n</sub>           | +16                  | 31  | 6'2  | 0'8218                        | +0'21                  | -2'2 | 10             |
| 6        | 17 10 13                | +2 1'47          | - 3 37'7         | 8-8              | 14                   | 7   | 19'54 | 9'5771 <sub>n</sub>           | +15                  | 45  | 48'9 | 0'8197                        | +0'24                  | -2'3 | 11             |
| 14       | 17 9 36                 | +0 7'65          | + 2 35'6         | 6-6              | 14                   | 35  | 23'40 | 9'5709 <sub>n</sub>           | +12                  | 48  | 23'4 | 0'8255                        | +0'34                  | -1'6 | 12             |
| 15       | 17 25 52                | +3 4'12          | - 9 37'7         | 7-7              | 14                   | 38  | 45'54 | 9'5670 <sub>n</sub>           | +12                  | 26  | 0'9  | 0'8206                        | +0'35                  | -1'8 | 13             |
| 16       | 17 16 58                | +5 44'87         | - 4 2'3          | 6-6              | 14                   | 42  | 3'09  | 9'5684 <sub>n</sub>           | +12                  | 4   | 46'9 | 0'8242                        | +0'37                  | -1'9 | 14             |

| 1887.<br>Dec. 6 | Greenwich Mean Time. |    |    | Comet—Star. |       |   | No. of Comps. | Comet's App. R.A. |    |       | Log ( $p \times \Delta$ ). | Comet's App. Dec. |    |      | Log ( $p \times \Delta$ ). | Red. to App. Place. | Comp. Star. |
|-----------------|----------------------|----|----|-------------|-------|---|---------------|-------------------|----|-------|----------------------------|-------------------|----|------|----------------------------|---------------------|-------------|
|                 | h                    | m  | s  | Δa.         | m     | s |               | h                 | m  | s     |                            | °                 | '  | "    |                            |                     |             |
| 8               | 17                   | 33 | 49 | +1          | 8.45  |   | 9-9           | 15                | 40 | 57.31 | 9.5477 <sub>n</sub>        | +5                | 37 | 56.6 | 0.8306                     | +0.66               | 15          |
| 10              | 17                   | 27 | 27 | -0          | 23.41 |   | 6-6           | 15                | 46 | 10.42 | 9.5492 <sub>n</sub>        | +5                | 4  | 16.5 | 0.8324                     | +0.70               | 16          |
| 13              | 17                   | 36 | 4  | +1          | 7.10  |   | 8-8           | 15                | 51 | 17.87 | 9.5429 <sub>n</sub>        | +4                | 31 | 18.9 | 0.8322                     | +0.73               | 17          |
| 16              | 17                   | 26 |    | +3          | 1.60  |   | 5-5           | 15                | 58 | 49.82 | 9.5156 <sub>n</sub>        | +3                | 43 | 36.3 | 0.8308                     | +0.78               | 18          |
| 18              | 17                   | 49 | 48 | +1          | 5.47  |   | 8-8           | 16                | 6  | 3.03  | 9.5265 <sub>n</sub>        | +2                | 58 | 12.2 | 0.8340                     | +0.84               | 19          |
| 27              | 18                   | 1  | 47 | -2          | 17.55 |   | 8-8           | 16                | 10 | 46.61 | 9.5132 <sub>n</sub>        | +2                | 29 | 1.7  | 0.8345                     | +0.87               | 20          |
| 1888.<br>Jan. 8 | 18                   | 0  | 47 | +1          | 15.56 |   | 4-4           | 16                | 30 | 48.10 | 9.4979 <sub>n</sub>        | +0                | 28 | 46.4 | 0.8400                     | +1.04               | 21          |
| 9               | 17                   | 42 | 45 | -0          | 48.58 |   | 8-8           | 16                | 54 | 44.46 | 9.4922 <sub>n</sub>        | -1                | 45 | 45.5 | 0.8468                     | -1.84               | 22          |
| Feb. 10         | 17                   | 49 | 19 | -4          | 3.28  |   | 8-8           | 16                | 56 | 37.24 | 9.4817 <sub>n</sub>        | -1                | 56 | 0.4  | 0.8476                     | -1.83               | 23          |
|                 | 17                   | 12 | 40 | -1          | 26.65 |   | 4-4           | 17                | 45 | 47.81 | 9.4227 <sub>n</sub>        | -6                | 0  | 57.5 | 0.8633                     | -1.22               | 24          |

## Notes.

- October 12.—Definition bad.  
 October 17-25.—Comet faint owing to the coming daylight during the later comparisons.  
 November 4.—The observation was obtained with difficulty between clouds, and hence is rather doubtful.  
 November 14.—Observation interrupted by passing clouds.  
 November 13.—Interrupted by clouds. Comet faint owing to the coming daylight during the later comparisons.  
 December 16.—Very windy; the clock heard with difficulty.  
 January 8.—Comet rather faint.  
 February 10.—The comet has become sensibly fainter since the last observation. Interrupted by clouds.
- October 13-19.—Comet faint from haze during the earlier comparisons.  
 December 8.—Interrupted by clouds passing. Rather windy.  
 December 27.—Interrupted by clouds passing.  
 January 9.—Comet faint owing to fog and the coming dawn.

Comet I, 1888 (*Sawerthal*).

| 1888.<br>April | Greenwich<br>Mean Time. |    |    | Comet—Star.      |                  |                  | No. of<br>Comps. | Comet's<br>App. R.A. |       |                     | Log<br>( $p \times \Delta$ ). | Comet's<br>App. Dec. |      |        | Log<br>( $p \times \Delta$ ). | Red. to App.<br>Place. | Comp.<br>Star. |
|----------------|-------------------------|----|----|------------------|------------------|------------------|------------------|----------------------|-------|---------------------|-------------------------------|----------------------|------|--------|-------------------------------|------------------------|----------------|
|                | h                       | m  | s  | $\Delta\alpha$ . | $\Delta\delta$ . | $\Delta\delta$ . |                  | h                    | m     | s                   |                               | °                    | '    | "      |                               |                        |                |
| 3              | 15                      | 56 | 34 | — 0 59'58        | — 5 30'3         | — 5 30'3         | 3-3              | 22                   | 9     | 24'31               | 9'5554 <sub>n</sub>           | + 5 58               | 46'8 | — 7'5  | 0'8323                        | — 0'99                 | 25             |
| 3              | 16                      | 9  | 34 | — 5 55'23        | — 2 11'3         | — 2 11'3         | 1-1              | 22                   | 9     | 26'38               | 9'5499 <sub>n</sub>           | + 5 59               | 21'3 | — 7'6  | 0'8304                        | — 1'01                 | 26             |
| 4              | 15                      | 53 | 24 | + 4 17'65        | — 9 24'0         | — 9 24'0         | 7-7              | 22                   | 12    | 25'81               | 9'5570 <sub>n</sub>           | + 7 0                | 8'7  | — 7'7  | 0'8307                        | — 0'96                 | 27             |
| 11             | 15                      | 38 | 21 | — 1 0'39         | — 3 6'3          | — 3 6'3          | 9-8              | 22                   | 33    | 4'22                | 9'5685 <sub>n</sub>           | + 13 31              | 23'0 | — 9'1  | 0'8172                        | — 0'89                 | 28             |
| 18             | 15                      | 19 | 29 | + 3 6'75         | + 4 42'5         | + 4 42'5         | 7-7              | 22                   | 52    | 38'17               | 9'5833 <sub>n</sub>           | + 19 2               | 23'3 | — 10'0 | 0'8054                        | — 0'79                 | 29             |
| 20             | 15                      | 13 | 21 | + 0 25'07        | + 8 27'5         | + 8 27'5         | 8-8              | 22                   | 58    | 0'54                | 9'5878 <sub>n</sub>           | + 20 27              | 18'4 | — 10'2 | 0'8028                        | — 0'78                 | 30             |
| May 1          | 15                      | 2  | 48 | + 4 6'05         | — 0 12'9         | — 0 12'9         | 6-6              | 23                   | 25    | 49'60               | 9'6095 <sub>n</sub>           | + 27 12              | 27'8 | — 11'3 | 0'7721                        | — 0'61                 | 31             |
| 5              | 14                      | 37 | 55 | + 1 50'59        | — 8 57'7         | — 8 57'7         | 7-7              | 23                   | 35    | 8'75                | 9'6202 <sub>n</sub>           | + 29 17              | 20'6 | — 11'6 | 0'7777                        | — 0'56                 | 32             |
| 7              | 13                      | 49 | 51 | + 2 45'79        | — 5 36'1         | — 5 36'1         | 8-8              | 23                   | 39    | 35'66               | 9'6181 <sub>n</sub>           | + 30 15              | 32'3 | — 11'7 | 0'8109                        | — 0'53                 | 33             |
| 8              | 13                      | 48 | 28 | — 1 45'49        | — 2 15'5         | — 2 15'5         | 8-8              | 23                   | 41    | 49'34               | 9'6203 <sub>n</sub>           | + 30 44              | 9'9  | — 11'7 | 0'8090                        | — 0'54                 | 34             |
| 10             | 13                      | 48 | 20 | — 1 19'08        | — 6 57'3         | — 6 57'3         | 9-9              | 23                   | 46    | 10'54               | 9'6257 <sub>n</sub>           | + 31 39              | 58'5 | — 11'8 | 0'8031                        | — 0'50                 | 35             |
| 11             | 13                      | 39 | 20 | + 1 26'67        | — 1 30'5         | — 1 30'5         | 8-8              | 23                   | 48    | 19'12               | 9'6254 <sub>n</sub>           | + 32 6               | 58'1 | — 11'8 | 0'8077                        | — 0'47                 | 36             |
| 12             | 13                      | 45 | 43 | + 3 10'86        | — 2 57'0         | — 2 57'0         | 9-9              | 23                   | 50    | 26'95               | 9'6302 <sub>n</sub>           | + 32 33              | 34'7 | — 11'9 | 0'7991                        | — 0'44                 | 37             |
| 13             | 13                      | 24 | 25 | + 3 50'02        | + 1 35'0         | + 1 35'0         | 8-8              | 23                   | 52    | 31'21               | 9'6251 <sub>n</sub>           | + 32 59              | 41'2 | — 11'9 | 0'8144                        | — 0'42                 | 38             |
| 13             | 13                      | 30 | 52 | + 2 5'75         | + 8 3'8          | + 8 3'8          | 6-6              | 23                   | 52    | 31'52               | 9'6279 <sub>n</sub>           | + 32 59              | 45'7 | — 11'9 | 0'8089                        | — 0'43                 | 39             |
| 23             | 11                      | 58 | 55 | + 4 53'92        | — 7 14'1         | — 7 14'1         | 7-7              | 0 11                 | 54'69 | 9'5959 <sub>n</sub> | 9'5959 <sub>n</sub>           | + 36 56              | 48'9 | — 12'2 | 0'8566                        | — 0'22                 | 40             |
| 26             | 11                      | 25 | 24 | — 0 53'64        | + 3 36'1         | + 3 36'1         | 9-9              | 0 17                 | 13'29 | 9'5682 <sub>n</sub> | 9'5682 <sub>n</sub>           | + 38 0               | 50'5 | — 12'2 | 0'8744                        | — 0'19                 | 41             |
| 27             | 11                      | 33 | 25 | — 3 41'45        | — 6 23'6         | — 6 23'6         | 8-8              | 0 18                 | 57'52 | 9'5842 <sub>n</sub> | 9'5842 <sub>n</sub>           | + 38 21              | 37'0 | — 12'3 | 0'8662                        | — 0'18                 | 42             |

|        | Greenwich Mean Time. |    |    | Comet—Star. |       | No. of Comps. | Comet's App. R.A. |    |       | Log ( $p \times \Delta$ ). | Comet's App. Dec. |    |      | Log ( $p \times \Delta$ ). | Red. to App. Place. |       | Comp Star |
|--------|----------------------|----|----|-------------|-------|---------------|-------------------|----|-------|----------------------------|-------------------|----|------|----------------------------|---------------------|-------|-----------|
|        | h                    | m  | s  | —           | m s   |               | h                 | m  | s     |                            | °                 | '  | "    |                            | s                   | "     |           |
| 1888.  |                      |    |    |             |       |               |                   |    |       |                            |                   |    |      |                            |                     |       |           |
| May 30 | 11                   | 18 | 45 | -3          | 31.07 | 8-8           | 0                 | 23 | 58.16 | 9.5797 <sub>n</sub>        | +39               | 22 | 12.7 | 0.8699                     | -0.11               | -12.3 | 43        |
| 31     | 11                   | 21 | 13 | +3          | 10.84 | 8-8           | 0                 | 25 | 36.01 | 9.5882 <sub>n</sub>        | +39               | 42 | 7.0  | 0.8658                     | -0.04               | -12.3 | 44        |
| June 3 | 12                   | 47 | 32 | +1          | 26.45 | 9-9           | 0                 | 30 | 24.23 | 9.6721 <sub>n</sub>        | +40               | 40 | 26.9 | 0.7767                     | -0.02               | -12.3 | 45        |
| 6      | 11                   | 8  | 48 | -2          | 54.33 | 8-8           | 0                 | 34 | 45.59 | 9.6030 <sub>n</sub>        | +41               | 34 | 16.1 | 0.8600                     | +0.07               | -12.3 | 46        |
| 13     | 11                   | 34 | 20 | -1          | 20.14 | 8-8           | 0                 | 41 | 34.20 | 9.6656 <sub>n</sub>        | +43               | 35 | 50.8 | 0.8122                     | +0.30               | -12.1 | 47        |
| July 3 | 12                   | 7  | 28 | -1          | 17.24 | 9-9           | 1                 | 3  | 2.25  | 9.7397 <sub>n</sub>        | +48               | 30 | 10.0 | 0.6642                     | +0.99               | -11.3 | 48        |
| Aug. 8 | 11                   | 28 | 15 | -1          | 12.40 | 8-8           | 0                 | 59 | 39.80 | 9.7484 <sub>n</sub>        | +54               | 23 | 29.5 | 0.3180                     | +2.66               | -5.2  | 49        |
| 10     | 11                   | 12 | 20 | -1          | 55.19 | 5-5           | 0                 | 57 | 51.09 | 9.7562 <sub>n</sub>        | +54               | 34 | 42.8 | 0.3351                     | +2.76               | -4.7  | 50        |

## Notes.

April 3.—Passing clouds. April 18.—Sky rather hazy. April 20.—Foggy, cloudy at times: comet rather faint in consequence.

May 5.—Comet rather fainter than expected (this is the first indication of variability of brightness noted).

May 12.—Sky hazy and the comet fainter in consequence.

May 23.—Sky very clear. Comet brighter than expected. This increase of brilliancy is noted by Dr. Schwarz, in Dorpat. (See *AN.* 2842) and others.

May 27.—Comet fainter; sky hazy.

May 31.—June 13.—The comparisons in R.A. are difficult and rather uncertain owing to the elongated form of the nucleus of the comet

in the direction of the parallel of declination.

June 3.—Sky hazy. Observation scarcely satisfactory.

July 3.—Comet much fainter than when last seen and difficult to observe with accuracy.

Aug. 8.—Comet very faint and the coma has almost disappeared. Nucleus small and starlike. On Aug. 2 the nucleus was indeed thought to be a small star within the coma, and no observation was then taken, as it was considered that such observation would be that of a star and would not accurately represent the place of the comet.

June 6.—Comet faint, owing to fog.

## Assumed Mean Places of Comparison Stars.

## Comet V. 1887.

| Comp.<br>Star. | R.A.<br>1887°0. |    |       | Decl.<br>1887°0. | Authority.                                                                                                                                                                                                                                               |
|----------------|-----------------|----|-------|------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                | h               | m  | s     | ° ' "            |                                                                                                                                                                                                                                                          |
| 1              | 9               | 53 | 5'31  | + 30 11 11'4     | $\frac{1}{4}$ (Gr. 9 yr. 949 + Gr. 7 yr. 1221 + Yarn-4162 + Arm., 2180).                                                                                                                                                                                 |
| 2              | 12              | 11 | 28'09 | + 25 15 10'5     | B.W. <sub>2</sub> 193. The R.A. of Lal. 23011, which is the same star, is 1°28 less.                                                                                                                                                                     |
| 3              | 12              | 23 | 47'78 | + 24 44 1'7      | 18 <i>Comæ</i> $\frac{1}{3}$ (2 Arm. <sub>1</sub> 2684 + Lal. 23357).                                                                                                                                                                                    |
| 4              | 12              | 25 | 25'01 | + 24 23 44'6     | $\frac{1}{2}$ (Yarn. 5217 + B.W. <sub>2</sub> 500-1).                                                                                                                                                                                                    |
| 5              | 12              | 41 | 31'88 | + 23 14 6'1      | B.W. <sub>2</sub> 822.                                                                                                                                                                                                                                   |
| 6              | 12              | 58 | 35'26 | + 22 30 5'0      | B.W. <sub>2</sub> 1124.                                                                                                                                                                                                                                  |
| 7              | 13              | 5  | 22'43 | + 21 50 15'8     | $\frac{1}{2}$ (Arm. <sub>2</sub> 1531 + B.W. <sub>2</sub> 45-6). The declination of Arm. <sub>2</sub> 1531 is about 1' less; that of Weisse is confirmed by Lal. 24505, the same star with an erroneous R.A.                                             |
| 8              | 13              | 16 | 14'27 | + 20 17 45'0     | Equat. comparison with Arm. <sub>1</sub> 2838                                                                                                                                                                                                            |
| 9              | 13              | 35 | 9'63  | + 19 9 51'6      | B.W. <sub>2</sub> 676-7.                                                                                                                                                                                                                                 |
| 10             | 14              | 2  | 29'01 | + 16 35 49'2     | B.W. <sub>2</sub> 1341.                                                                                                                                                                                                                                  |
| 11             | 14              | 5  | 17'83 | + 15 49 29'0     | $\frac{1}{2}$ (B.W. <sub>2</sub> 61 + Lal. 26005).                                                                                                                                                                                                       |
| 12             | 14              | 35 | 15'41 | + 12 45 49'4     | $\frac{1}{3}$ (2 Glasg. 3625 + B.W. <sub>1</sub> 619).                                                                                                                                                                                                   |
| 13             | 14              | 35 | 41'07 | + 12 35 40'3     | $\frac{1}{3}$ (2 Glasg. 3631 + B.W. <sub>1</sub> 628).                                                                                                                                                                                                   |
| 14             | 14              | 36 | 17'84 | + 12 8 51'1      | 32 <i>Boötis</i> $\frac{1}{4}$ (Glasg. 3635 + Arm. <sub>1</sub> 3101 + B.W. <sub>1</sub> 638 + Lal. 26777). The proper motion of this star from a comparison of the above catalogues, and Bradley 1879 appears to be -0°011 in R.A. and -0''145 in decl. |
| 15             | 15              | 39 | 48'19 | + 5 48 9'5       | $\frac{1}{3}$ (2 Arm. <sub>2</sub> 1837 + Lal. 28716).                                                                                                                                                                                                   |
| 16             | 15              | 46 | 33'13 | + 4 58 32'5      | $\frac{1}{2}$ (Lam. 1850 + Equat. comparison with <i>ε Serpentis</i> ).                                                                                                                                                                                  |
| 17             | 15              | 50 | 10'04 | + 4 39 54'7      | $\frac{1}{4}$ (2 Glasg. 3919 + B.W. <sub>1</sub> 922 + Lal. 28995-6).                                                                                                                                                                                    |
| 18             | 16              | 1  | 50'64 | + 3 42 46'8      | $\frac{1}{3}$ (Glasg. 3968 + Arm. <sub>2</sub> 1887 + Lam. 1943). This star has possibly proper motion in declination only. None, however, is assumed.                                                                                                   |
| 19             | 16              | 4  | 56'72 | + 2 55 0'0       | $\frac{1}{2}$ (Glasg. 3987 + Arm. <sub>2</sub> 1895).                                                                                                                                                                                                    |
| 20             | 16              | 13 | 3'29  | + 2 29 35'8      | B.B. vi. + 2° 30'6.                                                                                                                                                                                                                                      |
| 21             | 16              | 29 | 31'50 | + 0 30 40'9      | $\frac{1}{2}$ (Lam. 5205 + Equat. comparison with Glasg. 4093).                                                                                                                                                                                          |
|                | 1888°0.         |    |       | 1888°0.          |                                                                                                                                                                                                                                                          |
| 22             | 16              | 55 | 34'88 | - 1 42 59'0      | $\frac{1}{4}$ (Lam. 5433 + B.W. <sub>1</sub> 1017 + Schj. 6055 + Equat. comparison with Glasg. 4217).                                                                                                                                                    |
| 23             | 17              | 0  | 42'35 | - 1 47 17'7      | B.B. vi. - 1° 32'94.                                                                                                                                                                                                                                     |
| 24             | 17              | 47 | 15'68 | - 5 54 5'3       | $\frac{1}{4}$ (B.W. <sub>1</sub> 917 + Lam. 2491 + Arm. <sub>2</sub> 2119 + Cord. Zones).                                                                                                                                                                |

## Comet I. 1888.

| Comp.<br>Star. | R.A.<br>1887 <sup>o</sup> . |    |       | Decl.<br>1887 <sup>o</sup> . |    |         | Authority.                                                                                                                                                           |
|----------------|-----------------------------|----|-------|------------------------------|----|---------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                | h                           | m  | s     | °                            | '  | "       |                                                                                                                                                                      |
| 25             | 22                          | 10 | 24.88 | +                            | 6  | 4 24.7  | Schj. 9094.                                                                                                                                                          |
| 26             | 22                          | 15 | 22.62 | +                            | 6  | 1 40.3  | $\frac{1}{3}$ (2 Glasg. 5791 + B.W. <sub>1</sub> 271).                                                                                                               |
| 27             | 22                          | 8  | 9.12  | +                            | 7  | 9 40.4  | $\frac{1}{4}$ (2 Glasg. 5741 + B.W. <sub>1</sub> 114 + Lal. 43361-2).                                                                                                |
| 28             | 22                          | 34 | 5.50  | +                            | 13 | 34 38.4 | $\frac{1}{2}$ (Lam. 3147 + B.W. <sub>1</sub> 688).                                                                                                                   |
| 29             | 22                          | 49 | 32.21 | +                            | 18 | 57 50.7 | $\frac{1}{3}$ (Lam. 1728 + B.W. <sub>2</sub> 1109 + Lal. 44837).                                                                                                     |
| 30             | 22                          | 57 | 36.25 | +                            | 20 | 19 1.1  | $\frac{1}{3}$ (2 Arm. <sub>2</sub> 3116 + B.W. <sub>2</sub> 1279).                                                                                                   |
| 31             | 23                          | 21 | 44.16 | +                            | 27 | 12 52.0 | Equat. comparison with B.W. <sub>2</sub> 296 and B.W. <sub>2</sub> 384.                                                                                              |
| 32             | 23                          | 33 | 18.73 | +                            | 29 | 26 29.8 | B.W. <sub>2</sub> 692.                                                                                                                                               |
| 33             | 23                          | 36 | 50.40 | +                            | 30 | 21 20.1 | B.W. <sub>2</sub> 777-8.                                                                                                                                             |
| 34             | 23                          | 43 | 35.37 | +                            | 30 | 46 37.1 | Equat. comparison with B.W. <sub>2</sub> 860 and B.W. <sub>2</sub> 991.                                                                                              |
| 35             | 23                          | 47 | 30.12 | +                            | 31 | 47 7.6  | Lal. 46809.                                                                                                                                                          |
| 36             | 23                          | 46 | 52.92 | +                            | 32 | 8 40.5  | A.N. 2861 (Leiden A. G. Zones 118-123).                                                                                                                              |
| 37             | 23                          | 47 | 16.53 | +                            | 32 | 36 43.6 | B.W. <sub>2</sub> 966.                                                                                                                                               |
| 38             | 23                          | 48 | 41.61 | +                            | 32 | 58 18.1 | $\frac{1}{2}$ (B.W. <sub>2</sub> 989 + Lal. 46847).                                                                                                                  |
| 39             | 23                          | 50 | 26.20 | +                            | 32 | 51 53.8 | $\frac{1}{4}$ (2 Arm. <sub>2</sub> 3270 + B.W. <sub>2</sub> 1020 + Lal. 46911-2). The R.A. of Bessel appears to be 1° too great. It has been diminished accordantly. |
| 40             | 0                           | 7  | 0.98  | +                            | 37 | 4 15.2  | $\frac{1}{2}$ (Yarn. 59 + Paris Observations).                                                                                                                       |
| 41             | 0                           | 18 | 7.12  | +                            | 37 | 57 26.6 | R <i>Andromedæ</i> , B.B. vi. + 37° 58.                                                                                                                              |
| 42             | 0                           | 22 | 39.16 | +                            | 38 | 28 12.9 | $\frac{1}{2}$ (B.W. <sub>2</sub> 530 + Lal. 618).                                                                                                                    |
| 43             | 0                           | 27 | 29.34 | +                            | 39 | 29 14.1 | $\frac{1}{4}$ (2 Arm. <sub>2</sub> 81 + B.W. <sub>2</sub> 656-7 + Lal. 788-9).                                                                                       |
| 44             | 0                           | 22 | 25.21 | +                            | 39 | 39 45.5 | $\frac{1}{2}$ (B.W. <sub>2</sub> 524 + Lal. 606).                                                                                                                    |
| 45             | 0                           | 28 | 57.76 | +                            | 40 | 45 15.5 | $\frac{1}{2}$ (B.W. <sub>2</sub> 689 + Lal. 836).                                                                                                                    |
| 46             | 0                           | 37 | 39.85 | +                            | 41 | 40 3.7  | Equat. comparison with B.B. vi. + 41° 126.                                                                                                                           |
| 47             | 0                           | 42 | 54.04 | +                            | 43 | 31 19.8 | $\frac{1}{2}$ (B.W. <sub>2</sub> 1058 + Lal. 1303).                                                                                                                  |
| 48             | 1                           | 4  | 18.50 | +                            | 48 | 34 3.9  | $\frac{1}{2}$ (Radc. <sub>1</sub> 356 + Arg. Oe. <sub>1</sub> 1181).                                                                                                 |
| 49             | 1                           | 0  | 49.54 | +                            | 54 | 22 12.9 | $\mu$ <i>Cassiopeiæ</i> $\frac{1}{3}$ (Gr. 9 yr. 103 + Yarn. 565 + Radc. <sub>1</sub> 329).                                                                          |
| 50             | 0                           | 59 | 43.52 | +                            | 54 | 39. 9.1 | Equat. comparison with $\theta$ <i>Cassiopeiæ</i> and Radc. <sub>1</sub> 334.                                                                                        |

Col. Tomline's Observatory, Orwell Park:  
1888, November 23.

*Observations of Comets a 1888 (Sawerthal), and e 1888 (Barnard), made at the Royal Observatory, Greenwich.*

(Communicated by the Astronomer Royal.)

The observations were made with the East or Sheepshanks equatorial, aperture 6·7 inches, by taking transits over two cross wires at right angles to each other, and each inclined 45° to the parallel of declination.

*Comet a 1888 (Sawerthal).*

| Greenwich Mean<br>Solar Time.<br>1888. d h m s | Observer. | ♄-★<br>R.A. |       | Corr. for<br>Par. Refraction |         | ♄-★ <sup>1</sup><br>N.P.D. |      | Corr. for<br>Par. Refraction |            | No. of<br>Comp. | Apparent<br>R.A. |            |            | Apparent<br>N.P.D. |            |            | Comp.<br>Star |
|------------------------------------------------|-----------|-------------|-------|------------------------------|---------|----------------------------|------|------------------------------|------------|-----------------|------------------|------------|------------|--------------------|------------|------------|---------------|
|                                                |           | m s         | s     | s                            | s       | ' "                        | "    | "                            | "          |                 | h m s            | o ' "      | o ' "      | o ' "              | o ' "      | o ' "      |               |
| June 8 10 59 11                                | T.        | -0 17'12    | -0'20 | 0'00                         | -3 6'3  | -3'8                       | -0'5 | 8                            | ...        | a               | ...              | ...        | ...        | ...                | ...        | ...        | a             |
| 11 5 42                                        | ...       | +1 33'75    | -0'20 | 0'00                         | +4 34'9 | -3'7                       | +0'8 | 2                            | ...        | b               | ...              | ...        | ...        | ...                | ...        | ...        | b             |
| 11 7 43                                        | ...       | +1 31'50    | -0'20 | 0'00                         | +2 52'2 | -3'7                       | +0'5 | 1                            | 0 37 34'50 | c               | 47 49 44'1       | 47 49 44'1 | 47 49 44'1 | 47 49 44'1         | 47 49 44'1 | 47 49 44'1 | c             |
| 9 11 13 12                                     | H.        | -4 15'68    | -0'20 | 0'00                         | -4 38'2 | -3'6                       | -0'6 | 4                            | 0 38 57'03 | d               | 47 32 29'3       | 47 32 29'3 | 47 32 29'3 | 47 32 29'3         | 47 32 29'3 | 47 32 29'3 | d             |
| 11 11 36 41                                    | T.        | -0 31'50    | -0'20 | 0'00                         | +2 11'5 | -3'4                       | +0'2 | 2                            | ...        | e               | ...              | ...        | ...        | ...                | ...        | ...        | e             |
| 28 11 15 53                                    | A. D.     | +0 11'17    | -0'20 | 0'00                         | -12 1'3 | -2'9                       | -0'6 | 3                            | 0 59 24'77 | f               | 42 37 16'9       | 42 37 16'9 | 42 37 16'9 | 42 37 16'9         | 42 37 16'9 | 42 37 16'9 | f             |
| 11 27 19                                       | ...       | -1 22'56    | -0'22 | 0'00                         | +4 40'7 | -2'8                       | +0'2 | 5                            | 0 59 31'62 | g               | 42 37 29'4       | 42 37 29'4 | 42 37 29'4 | 42 37 29'4         | 42 37 29'4 | 42 37 29'4 | g             |
| July 10 12 12 16                               | H.        | +0 16'55    | -0'30 | 0'00                         | -2 0'2  | -2'5                       | -0'1 | 2                            | 1 6 10'45  | h               | 40 2 32'2        | 40 2 32'2  | 40 2 32'2  | 40 2 32'2          | 40 2 32'2  | 40 2 32'2  | h             |
| 12 24 51                                       | ...       | -0 20'80    | -0'30 | 0'00                         | +1 14'8 | -2'5                       | 0'0  | 1                            | ...        | i               | ...              | ...        | ...        | ...                | ...        | ...        | i             |

## Mean Places of Comparison Stars.

|          | Star's Name.             | R.A., 1880. |    |       | N.P.D., 1880. |    |      | Authority.                  |
|----------|--------------------------|-------------|----|-------|---------------|----|------|-----------------------------|
|          |                          | h           | m  | s     | °             | '  | "    |                             |
| <i>a</i> | Arg. Zone + 41°, No. 120 | 0           | 37 | 52    | 47            | 54 |      | Bonn Observations, vol. v.  |
| <i>b</i> | Arg. Zone + 42°, No. 151 | 0           | 36 | 2     | 47            | 46 |      | " "                         |
| <i>c</i> | Arg. Zone + 42°, No. 152 | 0           | 36 | 3.04  | 47            | 46 | 42.9 | " "                         |
| <i>d</i> | Arg. Zone + 42°, No. 181 | 0           | 43 | 12.74 | 47            | 36 | 59.5 | " "                         |
| <i>e</i> | Arg. Zone + 42°, No. 174 | 0           | 42 | 10    | 46            | 56 |      | " "                         |
| <i>f</i> | Oeltz. Arg. (N.) 1075    | 0           | 59 | 12.96 | 42            | 49 | 23.2 | Oeltz. Arg. (N)             |
| <i>g</i> | Oeltz. Arg. (N.) 1111    | 1           | 0  | 53.65 | 42            | 32 | 39.7 | " "                         |
| <i>h</i> | Arg. Zone + 49°, No. 322 | 1           | 5  | 52.91 | 40            | 4  | 24.4 | Bonn Observations, vol. vi. |
| <i>i</i> | Arg. Zone + 49°, No. 324 | 1           | 6  | 35    | 40            | 1  |      | " "                         |

## Notes.

June 8.—Comet very faint.

June 11.—Comet very faint indeed. Cloudy.

June 28.—Comet with stellar nucleus (about as bright as a 10th magnitude star) and straight tail, which is traceable for about 6'.  
 July 10.—Comet was only a very faint patch of light. No perceptible nucleus.

The observations are corrected for parallax and refraction.

The initials A.D., T., and H., are those of Mr. Downing, Mr. Thackeray, and Mr. Hollis, respectively.

*Comet e* 1888 (*Barnard*).

| Greenwich Mean<br>Solar Time. |      |       | Observer. | #-*      |       | Corr. for |      | #-*     | Par.   |            | Corr. for  | No. of | Apparent |       |       | Apparent | Comp.    |
|-------------------------------|------|-------|-----------|----------|-------|-----------|------|---------|--------|------------|------------|--------|----------|-------|-------|----------|----------|
| d                             | h    | m     |           | R.A.     | s     | Par.      | s    | N.P.D.  | N.P.D. | Refraction | Refraction |        | h        | m     | s     | N.P.D.   |          |
| 1888.<br>Nov. 26              | 8    | 6 41  | L.        | m        | s     | -0'20     | 0'00 | +0 51'1 | -6'6   | +0'1       | +0'1       | 6      | o        | '     | ...   | ...      | <i>a</i> |
|                               | 8    | 27 11 | ...       | -0 31'72 | -0'20 | 0'00      | 0'00 | +5 51'7 | -6'6   | +0'4       | ...        | 6      | ...      | ...   | ...   | ...      | <i>b</i> |
| 27                            | 8 44 | 8     | H. T.     | -0 16'27 | -0'10 | 0'00      | 0'00 | +5 39'7 | -6'6   | +0'4       | ...        | 3      | 2 42     | 32'23 | 95 26 | 0'7      | <i>c</i> |
|                               | 8 47 | 6     | ...       | +2 3'53  | -0'10 | 0'00      | 0'00 | +0 37'5 | -6'6   | 0'0        | ...        | 4      | 2 42     | 30'33 | 95 26 | 6'5      | <i>d</i> |
| Dec. 11                       | 9 42 | 25    | H.        | -0 31'40 | +0'10 | 0'00      | 0'00 | -4 14'7 | -5'8   | -0'3       | ...        | 2      | 1 22     | 16'30 | 97 28 | 59'3     | <i>e</i> |
|                               | 9 58 | 57    | ...       | -1 17'93 | +0'10 | 0'00      | 0'00 | +3 36'1 | -5'8   | +0'3       | ...        | 3      | 1 22     | 13'67 | 97 28 | 50'7     | <i>f</i> |
| 12                            | 6 41 | 5     | T.        | -0 24'58 | -0'10 | 0'00      | 0'00 | +2 15'1 | -5'7   | +0'1       | ...        | 6      | 1 18     | 20'42 | 97 31 | 58'3     | <i>g</i> |
|                               | 6 41 | 5     | ...       | -0 52'5  | -0'10 | 0'00      | 0'00 | -1 51'6 | -5'7   | -0'1       | ...        | 6      | 1 18     | 20'70 | 97 31 | 58'6     | <i>h</i> |

## Mean Places of Comparison Stars.

|          | Star's Name.             | R.A., 1880. |    |       | N.P.D., 1880. |    |      | Authority.                    |
|----------|--------------------------|-------------|----|-------|---------------|----|------|-------------------------------|
|          |                          | h           | m  | s     | °             | '  | "    |                               |
| <i>a</i> | Schönfeld's Zones—5° 540 | 2           | 48 | 44    | 95            | 17 |      | Bonn Observations, vol. viii. |
| <i>b</i> | Schönfeld's Zones—4° 494 | 2           | 48 | 58    | 95            | 8  |      | " " "                         |
| <i>c</i> | W. B., II., 707          | 2           | 42 | 45.71 | 95            | 20 | 32.4 | Weisse's Bessel.              |
| <i>d</i> | W. B., II., 666          | 2           | 40 | 24.01 | 95            | 25 | 44.2 | Paris Catalogue, 1875.        |
| <i>e</i> | W. B., I., 352           | 1           | 22 | 45.10 | 97            | 33 | 29.2 | Weisse's Bessel.              |
| <i>f</i> | W. B., I., 563           | 1           | 23 | 28.97 | 97            | 25 | 39.3 | Bonn Observations, vol. vi.   |
| <i>g</i> | W. B., I., 271           | 1           | 18 | 42.63 | 97            | 29 | 58.8 | Paris Catalogue, 1845.        |
| <i>h</i> | W. B., I., 283           | 1           | 19 | 10.77 | 97            | 34 | 5.1  | Weisse's Bessel.              |

## Notes.

Nov. 26.—Comet has very bright nucleus. The envelope extends half way to star *a*.

Dec. 11.—Comet very faint. Bright moonlight and mist.

Dec. 12.—Comet very faint indeed. Bright moonlight.

The observations are corrected for parallax and refraction.

The initials H.T., T., L., and H., are those of Mr. Turner, Mr. Thackeray, Mr. Lewis, and Mr. Hollis, respectively.

*Observations of Comet e 1888 with the Transit Circle.*

| Greenwich Mean<br>Solar Time. | Observer. | R.A. |    |       | N.P.D. (corrected for<br>Refraction and Parallax). | Remarks.                                                                                                           |
|-------------------------------|-----------|------|----|-------|----------------------------------------------------|--------------------------------------------------------------------------------------------------------------------|
|                               |           | h    | m  | s     |                                                    |                                                                                                                    |
| 1888. d    h    m    s        |           |      |    |       |                                                    |                                                                                                                    |
| Nov. 27 10 13    6            | T.        | 2    | 42 | 6.12  | 95   26   56.79                                    | Cloudy. Observed in dark field with wires illuminated.                                                             |
| Dec. 1    9 31 43             | T.        | 2    | 16 | 22.40 | 96   17   48.42                                    | Very faint indeed. Observed in dark field with wires illuminated.                                                  |
| 5    8 52 35                  | H.        | 1    | 52 | 53.78 | 96   55   12.50                                    | Dark field. The comet was faint and the illuminated wires hardly visible. The observation is therefore very rough. |
| 7    8 33 58                  | L.        | 1    | 42 | 6.75  | 97    9    6.48                                    |                                                                                                                    |
| 12    7 50 21                 | A. D.     | 1    | 18 | 5.75  | 97   31   54.80                                    | Very uncertain observation. Illuminated wires not visible, owing to strong moonlight.                              |

The initials A.D., T., L., and H., are those of Mr. Downing, Mr. Thackeray, Mr. Lewis, and Mr. Hollis, respectively.

*Observations of Comet Barnard (1888, September 2) made at the Radcliffe Observatory, Oxford.*

(Communicated by E. J. Stone, F.R.S., Radcliffe Observer.)

The following observations were made with the Barclay equatorial, using the ring-micrometer, with power 100.

| 1888.   | G.M.T. |    |    | Local Sidereal Time. |    |    | Observer. | Comet—Star<br>(Corrected for Refrac-<br>tion only.) |    |    | No. of<br>com-<br>pari-<br>sons. | Apparent R.A.<br>of Comet. |    |    | Parallax<br>in<br>$\frac{p}{s}$ | Log<br>of Comet. | Apparent N.P.D.<br>of Comet. |    |   | Parallax<br>in<br>$\frac{p}{q}$ | Refer-<br>ence to<br>Compa-<br>rison<br>Star. |    |   |    |   |    |    |    |    |     |     |
|---------|--------|----|----|----------------------|----|----|-----------|-----------------------------------------------------|----|----|----------------------------------|----------------------------|----|----|---------------------------------|------------------|------------------------------|----|---|---------------------------------|-----------------------------------------------|----|---|----|---|----|----|----|----|-----|-----|
|         | h      | m  | s  | h                    | m  | s  |           | R.A.                                                | m  | s  |                                  | h                          | m  | s  |                                 |                  | '                            | "  | ° |                                 |                                               | '  | " |    |   |    |    |    |    |     |     |
| Oct. 5  | 14     | 17 | 7  | 3                    | 12 | 47 | R.        | +1                                                  | 28 | 34 | +3                               | 21                         | 36 | 7  | 6                               | 34               | 16                           | 04 | 9 | 45                              | 33                                            | 0  | ' | "  | 3 | 17 | 0  | 80 | 29 | (a) |     |
| Nov. 13 | 13     | 13 | 55 | 4                    | 43 | 10 | R.        | -0                                                  | 31 | 05 | -5                               | 7                          | 83 | 12 | 4                               | 17               | 9                            | 42 | 8 | 61                              | 52                                            | 91 | 8 | 35 | 3 | 6  | 20 | 0  | 84 | 59  | (b) |

*Assumed Places of Comparison Stars.*

| Comp. Star. | Mean R.A. 1888 <sup>o</sup> . |    |    | Reduction to Apparent R.A. |   |   | Mean N.P.D. 1888 <sup>o</sup> . |    |    | Reduction to Apparent N.P.D. |   |   | Authority.                                     |
|-------------|-------------------------------|----|----|----------------------------|---|---|---------------------------------|----|----|------------------------------|---|---|------------------------------------------------|
|             | h                             | m  | s  | h                          | m | s | °                               | '  | "  | °                            | ' | " |                                                |
| (a)         | 6                             | 32 | 46 | 13                         |   |   | 81                              | 55 | 44 | 03                           |   |   | Transit Circle Observation, 1888, December 12. |
| (b)         | 4                             | 17 | 37 | 55                         |   |   | 91                              | 13 | 49 | 30                           |   |   | Mean of Göttingen, 1875, Nos. 1164 and 1165.   |

*Mr. Robinson's Remarks.*

October 5.—Circular Nebulosity, about  $3\frac{1}{2}'$  diameter. Distinct nucleus of the 10th magnitude.

In the computations of the parallax the adopted value of the Sun's mean horizontal parallax is  $8''.85$  and the geocentric distances,  $\Delta$ , have been taken from the *Astronomische Nachrichten*, Nos. 2858, p. 32, and 2861, p. 80.

At  $13^{\text{h}} 29^{\text{m}} 10^{\text{s}}.0$  G.M.T. of November 13, or Local Sidereal Time  $4^{\text{h}} 58^{\text{m}} 27^{\text{s}}.6$ , a star of the 10th magnitude appeared to be occulted by the nucleus of the comet, which was estimated to be of the same brightness as the star. The R.A. and N.P.D. of the star obtained from three independent sets of comparisons with the star (b) on November 13, December 12, and December 22 are :—

| Epoch 1888.0 | h m s                       |    |      | Correction for<br>Reduction to<br>Appar. R.A. |                        | Correction for<br>Reduction to<br>Appar. N.P.D. |
|--------------|-----------------------------|----|------|-----------------------------------------------|------------------------|-------------------------------------------------|
|              | $\frac{\text{s}}{\text{p}}$ |    |      | $\frac{\text{s}}{\text{p}}$                   |                        | $\frac{\text{s}}{\text{p}}$                     |
|              | 4                           | 17 | 24.9 | + 2.92                                        | $91^{\circ} 8' 49''.9$ | - 6''.17                                        |

This would give the following places for the comet at the time of occultation :

| Apparent R.A.<br>of Comet.                   | Parallax<br>in R.A.<br>$\frac{\text{s}}{\text{p}}$ | Apparent N.P.D.<br>of Comet. | Parallax<br>in N.P.D.<br>$\frac{\text{s}}{\text{p}}$ | Observer.    |
|----------------------------------------------|----------------------------------------------------|------------------------------|------------------------------------------------------|--------------|
| $4^{\text{h}} 17^{\text{m}} 54^{\text{s}}.1$ | + 0''.06                                           | $91^{\circ} 8' 43''.7$       | - 6''.20                                             | Mr. Robinson |

The calculated motion between the observations with the ring-micrometer and the time of occultation, as given by the ephemeris, is  $-4^{\text{s}}.09$  in R.A. and  $+13''.10$  in N.P.D.

In the observations of Sawerthal's Comet, printed in the *Monthly Notices* for May, June, and November 1888, the logarithms of the parallaxes in R.A. and N.P.D. have been given under the headings  $\log p \times \Delta$ , computed with an adopted value of the Sun's mean distance equal to  $8''.85$ , and geocentric distances extracted from the ephemerides of the *Astronomische Nachrichten*, Nos. 2834, 2835, 2838, 2846. The symbol  $p$  does not therefore, in these results, denote the parallax in R.A. and N.P.D. respectively, but the factors which, when multiplied by  $\Delta$ , give the required parallaxes.

Radcliffe Observatory, Oxford :  
1888, December 14.

*Ephemeris for Physical Observations*

| Greenwich<br>Noon. | Angle of<br>Position of<br>M's Axis. | Latitude of                 |        | Annual<br>Parallax. | Longitude of M's<br>Central Meridian. |        | Corr.<br>for<br>Phase. |
|--------------------|--------------------------------------|-----------------------------|--------|---------------------|---------------------------------------|--------|------------------------|
|                    |                                      | Earth<br>above M's Equator. | Sun    |                     | I.                                    | II.    |                        |
| 1889.              |                                      |                             |        | A-L.                | L-O.                                  |        |                        |
| Feb. 26            | 357°492                              | -2°245                      | -2°404 | -9°777              | 138°269                               | 240°18 | 237°43 + 0°42          |
| Mar. 3             | 357°147                              | 2°228                       | 2°391  | 10°116              | 139°012                               | 309°31 | 268°41 '45             |
| 8                  | 356°827                              | 2°211                       | 2°377  | 10°401              | 139°702                               | 18°51  | 299°45 '47             |
| 13                 | 356°534                              | 2°195                       | 2°363  | 10°630              | 140°336                               | 87°77  | 330°56 '49             |
| 18                 | 356°268                              | 2°180                       | 2°349  | 10°800              | 140°910                               | 157°10 | 1°74 '51               |
| 23                 | 356°031                              | 2°166                       | 2°335  | 10°907              | 141°422                               | 226°50 | 32°98 '52              |
| 28                 | 355°825                              | 2°153                       | 2°321  | 10°948              | 141°869                               | 295°96 | 64°29 '52              |
| Apr. 2             | 355°652                              | -2°141                      | -2°307 | -10°919             | 142°246                               | 5°49   | 95°67 + 0°52           |
| 7                  | 355°512                              | 2°130                       | 2°293  | 10°818              | 142°551                               | 75°09  | 127°11 '51             |
| 12                 | 355°406                              | 2°120                       | 2°278  | 10°643              | 142°782                               | 144°76 | 158°62 '49             |
| 17                 | 355°334                              | 2°112                       | 2°263  | 10°391              | 142°937                               | 214°49 | 190°21 '47             |
| 22                 | 355°298                              | 2°105                       | 2°249  | 10°061              | 143°014                               | 284°29 | 221°86 '44             |
| 27                 | 355°299                              | 2°099                       | 2°234  | 9°653               | 143°013                               | 354°16 | 253°57 '41             |
| May 2              | 355°335                              | -2°094                      | -2°219 | -9°165              | 142°933                               | 64°09  | 285°35 + 0°37          |
| 7                  | 355°407                              | 2°091                       | 2°204  | 8°600               | 142°775                               | 134°08 | 317°18 '32             |
| 12                 | 355°514                              | 2°088                       | 2°188  | 7°959               | 142°541                               | 204°12 | 349°06 '28             |
| 17                 | 355°654                              | 2°086                       | 2°173  | 7°245               | 142°235                               | 274°21 | 21°00 '23              |
| 22                 | 355°826                              | 2°085                       | 2°157  | 6°462               | 141°861                               | 344°34 | 52°98 '18              |
| 27                 | 356°028                              | 2°085                       | 2°142  | 5°615               | 141°423                               | 54°50  | 84°99 '14              |
| June 1             | 356°256                              | -2°085                      | -2°126 | -4°711              | 140°928                               | 124°69 | 117°03 + 0°10          |
| 6                  | 356°507                              | 2°085                       | 2°110  | 3°758               | 140°384                               | 194°90 | 149°09 '06             |
| 11                 | 356°777                              | 2°085                       | 2°094  | 2°765               | 139°801                               | 265°11 | 181°15 '03             |
| 16                 | 357°061                              | 2°086                       | 2°078  | 1°743               | 139°188                               | 335°32 | 213°20 '01             |
| 21                 | 357°354                              | 2°086                       | 2°062  | -0°701              | 138°556                               | 45°50  | 245°23                 |
| 26                 | 357°652                              | 2°085                       | 2°045  | +0°350              | 137°915                               | 115°65 | 277°24                 |
| July 1             | 357°949                              | -2°084                      | -2°029 | 1°398               | 137°278                               | 185°76 | 309°21 - 0°01          |
| 6                  | 358°239                              | 2°082                       | 2°012  | 2°432               | 136°655                               | 255°83 | 341°12 '03             |
| 11                 | 358°518                              | 2°079                       | 1°996  | 3°440               | 136°058                               | 325°84 | 12°97 '05              |
| 16                 | 358°780                              | 2°076                       | 1°979  | 4°413               | 135°496                               | 35°77  | 44°76 '08              |
| 21                 | 359°021                              | 2°071                       | 1°962  | 5°342               | 134°979                               | 105°62 | 76°46 '12              |
| 26                 | 359°238                              | 2°066                       | 1°945  | 6°218               | 134°515                               | 175°39 | 108°08 '17             |
| 31                 | 359°427                              | 2°060                       | 1°928  | 7°033               | 134°112                               | 245°07 | 139°61 '22             |
| Aug. 5             | 359°584                              | -2°053                      | -1°911 | +7°782              | 133°775                               | 314°65 | 171°04 - 0°26          |
| 10                 | 359°708                              | 2°045                       | 1°893  | 8°460               | 133°510                               | 24°13  | 202°38 '31             |

of Jupiter, 1889. By A. Marth.

| Greenwich<br>Noon. | Diameter |       | Difference of limbs |          | Defect of Illumination. |                            | $d$          | $\omega$     |
|--------------------|----------|-------|---------------------|----------|-------------------------|----------------------------|--------------|--------------|
|                    | Equat.   | Polar | in A.R.             | in Decl. | Equat.                  | in A.R.<br>preceding limb. |              |              |
| 1889               |          |       | <sup>s</sup>        |          | <sup>s</sup>            |                            | <sup>o</sup> | <sup>o</sup> |
| Feb. 26            | 34'79    | 32'58 | 2'521               | 32'59    | 0'25                    | 0'018                      | 9'77         | 271'21       |
| Mar. 3             | 35'26    | 33'02 | 2'555               | 33'03    | '27                     | '020                       | 10'11        | '20          |
| 8                  | 35'75    | 33'48 | 2'590               | 33'49    | '29                     | '021                       | 10'39        | '20          |
| 13                 | 36'27    | 33'97 | 2'627               | 33'98    | '31                     | '022                       | 10'62        | '19          |
| 18                 | 36'82    | 34'48 | 2'666               | 34'49    | '33                     | '024                       | 10'79        | '19          |
| 23                 | 37'39    | 35'00 | 2'706               | 35'02    | '34                     | '024                       | 10'90        | '18          |
| 28                 | 37'97    | 35'55 | 2'748               | 35'57    | '34                     | '025                       | 10'94        | '17          |
| Apr. 2             | 38'57    | 36'12 | 2'792               | 36'14    | 0'35                    | 0'025                      | 10'91        | 271'16       |
| 7                  | 39'19    | 36'70 | 2'836               | 36'71    | '35                     | '025                       | 10'81        | '14          |
| 12                 | 39'82    | 37'29 | 2'881               | 37'30    | '34                     | '025                       | 10'63        | '12          |
| 17                 | 40'46    | 37'88 | 2'927               | 37'90    | '33                     | '024                       | 10'38        | '10          |
| 22                 | 41'10    | 38'48 | 2'973               | 38'50    | '31                     | '023                       | 10'05        | '08          |
| 27                 | 41'73    | 39'07 | 3'019               | 39'10    | '29                     | '021                       | 9'65         | '05          |
| May 2              | 42'35    | 39'65 | 3'064               | 39'68    | 0'27                    | 0'019                      | 9'16         | 271'02       |
| 7                  | 42'96    | 40'22 | 3'109               | 40'24    | '24                     | '017                       | 8'59         | 270'98       |
| 12                 | 43'54    | 40'77 | 3'152               | 40'79    | '21                     | '015                       | 7'95         | 270'93       |
| 17                 | 44'09    | 41'28 | 3'192               | 41'30    | '18                     | '013                       | 7'24         | 270'88       |
| 22                 | 44'60    | 41'76 | 3'230               | 41'78    | '14                     | '011                       | 6'46         | 270'82       |
| 27                 | 45'06    | 42'19 | 3'264               | 42'21    | '11                     | '008                       | 5'61         | 270'73       |
| June 1             | 45'46    | 42'57 | 3'294               | 42'59    | 0'08                    | 0'006                      | 4'71         | 270'62       |
| 6                  | 45'80    | 42'89 | 3'319               | 42'90    | '05                     | '004                       | 3'75         | 270'49       |
| 11                 | 46'07    | 43'14 | 3'340               | 43'15    | '03                     | '002                       | 2'76         | 270'26       |
| 16                 | 46'27    | 43'32 | 3'355               | 43'33    | '01                     | '001                       | 1'74         | 269'7        |
| 21                 | 46'39    | 43'43 | 3'365               | 43'44    | on following            |                            | 0'70         | 268'0        |
| 26                 | 46'42    | 43'47 | 3'368               | 43'47    | limb                    |                            | 0'35         | 97'0         |
| July 1             | 46'37    | 43'43 | 3'365               | 43'43    |                         |                            | 1'40         | 92'4         |
| 6                  | 46'25    | 43'31 | 3'357               | does     | 0'02                    | 0'002                      | 2'43         | 91'71        |
| 11                 | 46'05    | 43'12 | 3'343               | not      | '04                     | '003                       | 3'44         | 91'41        |
| 16                 | 45'77    | 42'86 | 3'323               | differ   | '07                     | '005                       | 4'41         | 91'26        |
| 21                 | 45'43    | 42'54 | 3'298               | from     | '10                     | '007                       | 5'34         | 91'15        |
| 26                 | 45'02    | 42'16 | 3'269               | polar    | '13                     | '010                       | 6'21         | 91'07        |
| 31                 | 44'56    | 41'73 | 3'236               | diameter | '17                     | '012                       | 7'03         | 91'01        |
| Aug. 5             | 44'06    | 41'26 | 3'200               |          | 0'20                    | 0'015                      | 7'78         | 90'97        |
| 10                 | 43'52    | 40'75 | 3'161               |          | '24                     | '017                       | 8'46         | '94          |

| Greenwich<br>Noon. | Angle of<br>Position of<br>$\mathcal{U}$ 's Axis. | Latitude of<br>Earth<br>above $\mathcal{U}$ 's Equator. | Sun<br>Equator. | Annual<br>Parallax. | Longitude of $\mathcal{U}$ 's<br>Central Meridian. |         |        |     | Corr.<br>for<br>Phase. |
|--------------------|---------------------------------------------------|---------------------------------------------------------|-----------------|---------------------|----------------------------------------------------|---------|--------|-----|------------------------|
|                    |                                                   |                                                         |                 |                     | $\Lambda-L$ .                                      | $L-O$ . | I.     | II. |                        |
| <sup>†</sup> 1889. |                                                   |                                                         |                 |                     |                                                    |         |        |     |                        |
| Aug. 15            | 359°797                                           | 2°036                                                   | 1°876           | 9°064               | 133°320                                            | 93°52   | 233°62 |     | °36                    |
| 20                 | 359°850                                           | 2°026                                                   | 1°858           | 9°591               | 133°207                                            | 162°81  | 264°77 |     | °40                    |
| 25                 | 359°866                                           | 2°015                                                   | 1°840           | 10°040              | 133°171                                            | 232°01  | 295°82 |     | °44                    |
| 30                 | 359°845                                           | 2°004                                                   | 1°823           | 10°410              | 133°215                                            | 301°11  | 326°77 |     | °47                    |
| Sept. 4            | 359°788                                           | -1°992                                                  | -1°805          | +10°702             | 133°338                                            | 10°12   | 357°64 |     | -0°50                  |
| 9                  | 359°694                                           | 1°979                                                   | 1°787           | 10°917              | 133°538                                            | 79°05   | 28°42  |     | °52                    |
| 14                 | 359°565                                           | 1°965                                                   | 1°769           | 11°057              | 133°813                                            | 147°89  | 59°11  |     | °53                    |
| 19                 | 359°402                                           | 1°950                                                   | 1°750           | 11°123              | 134°161                                            | 216°66  | 89°73  |     | °54                    |
| 24                 | 359°206                                           | 1°935                                                   | 1°732           | 11°119              | 134°581                                            | 285°35  | 120°28 |     | °54                    |
| 29                 | 358°977                                           | 1°919                                                   | 1°714           | 11°047              | 135°069                                            | 353°97  | 150°76 |     | °53                    |
| Oct. 4             | 358°718                                           | -1°902                                                  | -1°695          | +10°910             | 135°622                                            | 62°54   | 181°17 |     | -0°52                  |
| 9                  | 358°430                                           | 1°883                                                   | 1°676           | 10°712              | 136°237                                            | 131°05  | 211°53 |     | °50                    |
| 14                 | 358°116                                           | 1°864                                                   | 1°658           | 10°455              | 136°909                                            | 199°50  | 241°84 |     | °48                    |
| 19                 | 357°776                                           | 1°844                                                   | 1°639           | 10°144              | 137°636                                            | 267°91  | 272°10 |     | °45                    |
| 24                 | 357°412                                           | -1°823                                                  | -1°620          | +9°782              | 138°416                                            | 336°29  | 302°33 |     | 0°42                   |

The angle  $\Lambda-L$  is the difference of the Jovicentric longitudes of the Sun and Earth, reckoned in the plane of *Jupiter's* equator;  $L-O+180^\circ$  the Jovicentric longitude of the Earth reckoned from O, the point of the vernal equinox of *Jupiter's* northern hemisphere or the point of the ascending node of the planet's orbit on its equator.

Two values of the "longitude of  $\mathcal{U}$ 's central meridian" are given for each date: the first, computed with the daily rate of rotation  $877^\circ.90$ , being intended for comparing the observations of white spots in the neighbourhood of the planet's equator; the second, computed with the rate  $870^\circ.27$ , for the observations of the remnant of the great reddish spot in the planet's southern hemisphere. This latter rate is the same as that adopted in the ephemerides for the two preceding oppositions, but the zero-meridian has been put back  $10^\circ$  or the longitudes in the present ephemeris have been increased  $10^\circ$ , in order that the zero-meridian may precede the middle of the spot, at least in case the rate of the spot's motion does not become sensibly accelerated. The daily rate  $877^\circ.90$  of system I is approximately that of the motion of two bright spots, observed during the past apparition of *Jupiter* at Brighton by Mr. A. S. Williams, who has been good enough to communicate his observations to me, the only ones which have yet come to my knowledge. His few observations of an equatorial spot procured in 1887 seem to belong to one of these spots. But the irregularity and uncertainty of the motion, and the want of sufficient observations between 1885 and 1887 render it, for the present at least, not feasible to establish the

| Greenwich<br>Noon. | Diameter |        | Difference of limbs |          | Defect of illumination.             |        | <i>d</i> | <i>w</i> |
|--------------------|----------|--------|---------------------|----------|-------------------------------------|--------|----------|----------|
|                    | Equat.   | Polar  | in A.R.             | in Decl. | Equat.   in A.R.<br>preceding limb. |        |          |          |
| 1889               |          |        |                     |          |                                     |        |          |          |
| Aug. 15            | 42° 95   | 40° 22 | 3° 120              |          | ° 27                                | ° 019  | 9° 06    | ° 91     |
| 20                 | 42° 36   | 39° 66 | 3° 077              |          | ° 30                                | ° 021  | 9° 59    | ° 89     |
| 25                 | 41° 75   | 39° 09 | 3° 033              |          | ° 32                                | ° 023  | 10° 03   | ° 88     |
| 30                 | 41° 13   | 38° 52 | 2° 989              |          | ° 34                                | ° 025  | 10° 41   | ° 88     |
| Sept. 4            | 40° 52   | 37° 94 | 2° 944              |          | 0° 35                               | 0° 026 | 10° 70   | 90° 88   |
| 9                  | 39° 91   | 37° 37 | 2° 900              |          | ° 36                                | ° 026  | 10° 91   | ° 88     |
| 14                 | 39° 30   | 36° 80 | 2° 856              |          | ° 36                                | ° 026  | 11° 05   | ° 89     |
| 19                 | 38° 71   | 36° 24 | 2° 813              |          | ° 36                                | ° 026  | 11° 12   | ° 90     |
| 24                 | 38° 13   | 35° 70 | 2° 772              |          | ° 36                                | ° 026  | 11° 11   | ° 92     |
| 29                 | 37° 57   | 35° 18 | 2° 731              |          | ° 35                                | ° 025  | 11° 04   | ° 95     |
| Oct. 4             | 37° 03   | 34° 67 | 2° 692              |          | 0° 33                               | 0° 024 | 10° 91   | 90° 98   |
| 9                  | 36° 51   | 34° 19 | 2° 655              |          | ° 32                                | ° 023  | 10° 71   | 91° 00   |
| 14                 | 36° 02   | 33° 73 | 2° 619              |          | ° 30                                | ° 022  | 10° 45   | 91° 03   |
| 19                 | 35° 55   | 33° 29 | 2° 585              |          | ° 28                                | ° 020  | 10° 14   | 91° 07   |
| 24                 | 35° 11   | 32° 88 | 2° 552              |          | ° 26                                | 0° 019 | 9° 78    | 91° 11   |

connection between these spots and the chief white spot, observed from 1880 to 1886, especially assiduously by Mr. Denning at Bristol.—The differences of successive values of the longitudes of  $\mathcal{U}$ 's central meridian amount, for the interval of five days, to twelve rotations in addition to the differences directly deduced, so that, for instance, the differences of the first two values are  $4389^{\circ}13$  and  $4350^{\circ}98$ . The addition of the "correction for phase" to the longitudes of the central meridian gives the longitudes of the meridian which bisects the illuminated disc. A list of Greenwich times when these latter longitudes are  $0^{\circ}$  is given further on.

The diameters of the disc, &c., depend on the same assumed values as in the ephemerides for preceding years. The formulæ employed may be found in vol. xlv. p. 508.

The inclinations  $\gamma$  and the ascending nodes  $\Gamma$  of the orbits of the four satellites of *Jupiter* in reference to the assumed plane of the planet's equator are the following, the longitudes of the nodes being reckoned from O, the point of the ascending node of *Jupiter's* orbit on the equator:

|         | Sat. I.    |            | Sat. II.   |            | Sat. III.  |            | Sat. IV.   |            |
|---------|------------|------------|------------|------------|------------|------------|------------|------------|
|         | $\gamma_1$ | $\Gamma_1$ | $\gamma_2$ | $\Gamma_2$ | $\gamma_3$ | $\Gamma_3$ | $\gamma_4$ | $\Gamma_4$ |
| 1889.   |            |            |            |            |            |            |            |            |
| Feb. 26 | 0° 0106    | 271° 0     | 0° 4923    | 267° 38    | 0° 1342    | 245° 93    | 0° 3130    | 331° 47    |
| Apr. 27 | ° 0105     | 268° 7     | ° 4923     | 265° 45    | ° 1336     | 245° 51    | ° 3122     | 331° 44    |
| June 26 | ° 0103     | 266° 3     | ° 4923     | 263° 52    | ° 1331     | 245° 10    | ° 3114     | 331° 39    |
| Aug. 25 | ° 0102     | 264° 0     | ° 4923     | 261° 59    | ° 1327     | 244° 70    | ° 3107     | 331° 32    |
| Oct. 24 | 0° 0101    | 261° 8     | 0° 4924    | 259° 66    | 0° 1323    | 244° 31    | 0° 3100    | 331° 23    |

The following is a list of Greenwich mean times, when the zero meridian in the assumed two systems of longitudes will pass the middle of the illuminated disc :

|       |    | I.        |      | II.       |      |       |    | I.        |      | II.       |      |
|-------|----|-----------|------|-----------|------|-------|----|-----------|------|-----------|------|
|       |    | (877° 90) |      | (870° 27) |      |       |    | (877° 90) |      | (870° 27) |      |
|       |    | h         | m    | h         | m    |       |    | h         | m    | h         | m    |
| 1889. |    |           |      |           |      | 1889. |    |           |      |           |      |
| Feb.  | 26 | 13        | 6.4  | 13        | 17.9 | Apr.  | 1  | 13        | 59.6 | 11        | 25.2 |
|       | 27 | 18        | 38.1 | 19        | 5.0  |       | 2  | 19        | 31.1 | 17        | 12.2 |
|       | 28 | 14        | 19.1 | 14        | 56.5 |       | 3  | 15        | 12.1 | 13        | 3.5  |
| Mar.  | 1  | 19        | 50.8 | 20        | 43.7 |       | 4  | 10        | 53.1 | 18        | 50.5 |
|       | 2  | 15        | 31.9 | 16        | 35.1 |       | 5  | 16        | 24.5 | 14        | 41.8 |
|       | 3  | 11        | 12.9 | 12        | 26.5 |       | 6  | 12        | 5.5  | 10        | 33.2 |
|       | 4  | 16        | 44.6 | 18        | 13.7 |       | 7  | 17        | 37.0 | 16        | 20.2 |
|       | 5  | 12        | 25.6 | 14        | 5.1  |       | 8  | 13        | 17.9 | 12        | 11.5 |
|       | 6  | 17        | 57.3 | 19        | 52.3 |       | 9  | 18        | 49.4 | 17        | 58.5 |
|       | 7  | 13        | 38.3 | 15        | 43.6 |       | 10 | 14        | 30.3 | 13        | 49.8 |
|       | 8  | 19        | 9.9  | 11        | 35.1 |       | 11 | 10        | 11.3 | 9         | 41.1 |
|       | 9  | 14        | 51.0 | 17        | 22.3 |       | 12 | 15        | 42.7 | 15        | 28.0 |
|       | 10 | 10        | 32.1 | 13        | 13.7 |       | 13 | 11        | 23.7 | 11        | 19.3 |
|       | 11 | 16        | 3.6  | 19        | 0.8  |       | 14 | 16        | 55.1 | 17        | 6.3  |
|       | 12 | 11        | 44.7 | 14        | 52.2 |       | 15 | 12        | 36.0 | 12        | 57.6 |
|       | 13 | 17        | 16.3 | 10        | 43.6 |       | 16 | 8         | 17.0 | 8         | 48.9 |
|       | 14 | 12        | 57.3 | 16        | 30.7 |       |    | 18        | 7.4  | 18        | 44.5 |
|       | 15 | 18        | 28.9 | 12        | 22.1 |       | 17 | 13        | 48.4 | 14        | 35.8 |
|       | 16 | 14        | 9.9  | 18        | 9.2  |       | 18 | 9         | 29.3 | 10        | 27.1 |
|       | 17 | 19        | 41.5 | 14        | 0.6  |       |    | 19        | 19.8 | 20        | 22.7 |
|       | 18 | 15        | 22.5 | 19        | 47.7 |       | 19 | 15        | 0.7  | 16        | 14.0 |
|       | 19 | 11        | 3.5  | 15        | 39.1 |       | 20 | 10        | 41.6 | 12        | 5.3  |
|       | 20 | 16        | 35.1 | 11        | 30.4 |       | 21 | 16        | 13.0 | 17        | 52.2 |
|       | 21 | 12        | 16.1 | 17        | 17.5 |       | 22 | 11        | 53.9 | 13        | 43.4 |
|       | 22 | 17        | 47.6 | 13        | 8.9  |       | 23 | 17        | 25.3 | 9         | 34.7 |
|       | 23 | 13        | 28.6 | 18        | 55.9 |       | 24 | 13        | 6.2  | 15        | 21.6 |
|       | 24 | 19        | 0.1  | 14        | 47.3 |       | 25 | 8         | 47.1 | 11        | 12.9 |
|       | 25 | 14        | 41.2 | 10        | 38.7 |       | 26 | 14        | 18.5 | 16        | 59.8 |
|       | 26 | 10        | 22.2 | 16        | 25.7 |       | 27 | 9         | 59.4 | 12        | 51.0 |
|       | 27 | 15        | 53.7 | 12        | 17.1 |       | 28 | 15        | 30.7 | 8         | 42.3 |
|       | 28 | 11        | 34.7 | 18        | 4.1  |       | 29 | 11        | 11.6 | 14        | 29.2 |
|       | 29 | 17        | 6.2  | 13        | 55.5 |       | 30 | 16        | 42.9 | 10        | 20.4 |
|       | 30 | 12        | 47.2 | 19        | 42.5 | May   | 1  | 12        | 23.8 | 16        | 7.3  |
|       | 31 | 18        | 18.7 | 15        | 33.8 |       | 2  | 8         | 4.7  | 11        | 58.5 |

|       |     | I.        |         | II.       |   |       |      | I.                                                                                              |                                                             | II.       |   |
|-------|-----|-----------|---------|-----------|---|-------|------|-------------------------------------------------------------------------------------------------|-------------------------------------------------------------|-----------|---|
|       |     | (877° 90) |         | (870° 27) |   |       |      | (877° 90)                                                                                       |                                                             | (870° 27) |   |
|       |     | h         | m       | h         | m |       |      | h                                                                                               | m                                                           | h         | m |
| 1889. | May | 3         | 13 36.1 | 17 45.4   |   | 1889. | June | 3                                                                                               | 7 37.8                                                      | 8 19.7    |   |
|       |     | 4         | 9 16.9  | 13 36.6   |   |       |      |                                                                                                 | 17 28.2                                                     | 18 15.3   |   |
|       |     | 5         | 14 48.3 | 9 27.9    |   |       | 4    | 13 9.0                                                                                          | 14 6.5                                                      |           |   |
|       |     | 6         | 10 29.1 | 15 14.7   |   |       | 5    | 8 49.8                                                                                          | 9 57.7                                                      |           |   |
|       |     | 7         | 16 0.4  | 11 5.9    |   |       | 6    | 14 21.1                                                                                         | 15 44.4                                                     |           |   |
|       |     | 8         | 11 41.3 | 16 52.8   |   |       | 7    | 10 1.9                                                                                          | 11 35.6                                                     |           |   |
|       |     | 9         | 17 12.6 | 12 44.0   |   |       | 8    | 15 33.1                                                                                         | 17 22.3                                                     |           |   |
|       |     | 10        | 12 53.5 | 8 35.2    |   |       | 9    | 11 13.9                                                                                         | 13 13.5                                                     |           |   |
|       |     | 11        | 8 34.3  | 14 22.0   |   |       | 10   | 16 45.2                                                                                         | 9 4.7                                                       |           |   |
|       |     | 12        | 14 5.6  | 10 13.2   |   |       | 11   | 12 26.0                                                                                         | 14 51.4                                                     |           |   |
|       |     | 13        | 9 46.5  | 16 0.1    |   |       | 12   | 8 6.8                                                                                           | 10 42.6                                                     |           |   |
|       |     | 14        | 15 17.8 | 11 51.3   |   |       | 13   | 13 38.0                                                                                         | 16 29.3                                                     |           |   |
|       |     | 15        | 10 58.6 | 17 38.1   |   |       | 14   | 9 18.8                                                                                          | 12 20.5                                                     |           |   |
|       |     | 16        | 16 29.9 | 13 29.3   |   |       | 15   | 14 50.0                                                                                         | 8 11.7                                                      |           |   |
|       |     | 17        | 12 10.7 | 9 20.5    |   |       | 16   | 10 30.9                                                                                         | 13 58.4                                                     |           |   |
|       |     | 18        | 17 42.0 | 15 7.3    |   |       | 17   | 16 2.1                                                                                          | 9 49.6                                                      |           |   |
|       |     | 19        | 13 22.9 | 10 58.5   |   |       | 18   | 11 42.9                                                                                         | 15 36.4                                                     |           |   |
|       |     | 20        | 9 3.7   | 16 45.3   |   |       | 19   | 7 23.7                                                                                          | 11 27.5                                                     |           |   |
|       |     | 21        | 14 35.0 | 12 36.5   |   |       | 20   | 12 55.0                                                                                         | 7 18.7                                                      |           |   |
|       |     | 22        | 10 15.8 | 8 27.6    |   |       | 21   | 8 35.8                                                                                          | 13 5.5                                                      |           |   |
|       |     | 23        | 15 47.1 | 14 14.4   |   |       | 22   | 14 7.0                                                                                          | 8 56.6                                                      |           |   |
|       |     | 24        | 11 27.9 | 10 5.6    |   |       | 23   | 9 47.8                                                                                          | 14 43.4                                                     |           |   |
|       |     | 25        | 16 59.1 | 15 52.4   |   |       | 24   | Transit of Earth and Moon<br>across Sun's disc. <i>Vide M.</i><br><i>Not.</i> vol. xlv. p. 163. |                                                             |           |   |
|       |     | 26        | 12 40.0 | 11 43.6   |   |       |      |                                                                                                 |                                                             |           |   |
|       |     | 27        | 8 20.8  | 7 34.7    |   |       |      |                                                                                                 |                                                             |           |   |
|       |     |           | 18 11.2 | 17 30.3   |   |       |      | 15 19.1                                                                                         | 10 34.6                                                     |           |   |
|       |     | 28        | 13 52.0 | 13 21.5   |   |       | 25   | 10 59.9                                                                                         | 16 21.3                                                     |           |   |
|       |     | 29        | 9 32.9  | 9 12.7    |   |       | 26   | 16 31.2                                                                                         | 12 12.5                                                     |           |   |
|       |     |           | 19 23.3 | 19 8.3    |   |       | 27   | 12 12.0                                                                                         | 8 3.7                                                       |           |   |
|       |     | 30        | 15 4.1  | 14 59.5   |   |       | 28   | 7 52.8                                                                                          | 13 50.5                                                     |           |   |
|       |     | 31        | 10 44.9 | 10 50.6   |   |       | 29   | 9 22                                                                                            | Middle of<br>second tabular eclipse of<br><i>Sat. IV.</i> * |           |   |
| June  | 1   |           | 6 25.7  | 6 41.8    |   |       |      |                                                                                                 |                                                             |           |   |
|       |     |           | 16 16.2 | 16 37.4   |   |       |      | 13 24.1                                                                                         | 9 41.6                                                      |           |   |
|       | 2   |           | 11 57.0 | 12 28.6   |   |       | 30   | 9 4.9                                                                                           | 15 28.4                                                     |           |   |

\* There will be probably no real eclipse, but the satellite will remain visible as a speck of light skirting the margin of the total shadow. *Vide Monthly Notices*, vol. xlv. p. 243.

|       |    | I.                                    | II.       |       |    | I.                                | II.       |
|-------|----|---------------------------------------|-----------|-------|----|-----------------------------------|-----------|
|       |    | (877°·90)                             | (870°·27) |       |    | (877°·90)                         | (870°·27) |
|       |    | h m                                   | h m       |       |    | h m                               | h m       |
| 1889. |    |                                       |           | 1889. |    |                                   |           |
| July  | 1  | 14 36·2                               | 11 19·6   | July  | 29 | 11 46·9                           | 14 22·4   |
|       | 2  | 10 17·0                               | 7 10·8    |       | 30 | 7 27·9                            | 10 13·7   |
|       | 3  | 15 48·3                               | 12 57·6   |       | 31 | 12 58·4                           | 6 5·0     |
|       | 4  | 11 29·2                               | 8 48·9    | Aug.  | 1  | 8 40·3                            | 11 52·0   |
|       | 5  | 7 10·0                                | 14 35·7   |       |    | 18 30·8                           | 21 47·7   |
|       | 6  | 12 41·3                               | 10 26·9   |       |    | 21 29                             | Middle of |
|       | 7  | 8 22·2                                | 6 18·1    |       |    | second eclipse of <i>Sat. IV.</i> |           |
|       |    | 18 12·6                               | 16 13·7   |       | 2  | 14 11·8                           | 7 43·4    |
|       | 8  | 13 53·5                               | 12 4·9    |       | 3  | 9 52·8                            | 13 30·4   |
|       | 9  | 9 34·4                                | 7 56·2    |       | 4  | 5 33·8                            | 9 21·7    |
|       | 10 | 15 5·7                                | 13 43·0   |       |    | 15 24·3                           | 19 17·4   |
|       | 11 | 10 46·5                               | 9 34·2    |       | 5  | 11 5·3                            | 15 8·8    |
|       | 12 | 6 27·4                                | 5 25·5    |       | 6  | 6 46·3                            | 11 0·1    |
|       |    | 16 17·9                               | 15 21·1   |       | 7  | 12 17·8                           | 6 51·5    |
|       | 13 | 11 58·8                               | 11 12·3   |       | 8  | 7 58·9                            | 12 38·6   |
|       | 14 | 7 39·7                                | 7 3·6     |       | 9  | 13 30·4                           | 8 29·9    |
|       |    | 17 30·1                               | 16 59·2   |       | 10 | 9 11·4                            | 4 21·3    |
|       | 15 | 13 11·0                               | 12 50·4   |       |    | 19 1·9                            | 14 17·0   |
|       | 16 | 3 25                                  | Middle of |       | 11 | 4 52·5                            | 10 8·4    |
|       |    | first real eclipse of <i>Sat. IV.</i> |           |       |    | 14 43·0                           | 20 4·1    |
|       |    | Duration uncertain.                   |           |       | 12 | 10 24·0                           | 5 59·8    |
|       |    | 8 51·9                                | 8 41·7    |       |    | 20 14·5                           | 15 55·5   |
|       | 17 | 14 23·3                               | 14 28·6   |       | 13 | 6 5·1                             | 11 46·9   |
|       | 18 | 10 4·2                                | 10 19·9   |       | 14 | 11 36·6                           | 7 38·3    |
|       | 19 | 5 45·1                                | 6 11·1    |       | 15 | 7 17·7                            | 13 25·4   |
|       |    | 15 35·6                               | 16 6·8    |       | 16 | 12 49·3                           | 9 16·8    |
|       | 20 | 11 16·5                               | 11 58·0   |       | 17 | 8 30·4                            | 15 4·0    |
|       | 21 | 6 57·4                                | 7 49·3    |       | 18 | 14 2·0                            | 10 55·4   |
|       |    | 16 47·9                               | 17 45·0   |       |    | 15 34                             | Middle of |
|       | 22 | 12 28·8                               | 13 36·3   |       |    | third eclipse of <i>Sat. IV.</i>  |           |
|       | 23 | 8 9·8                                 | 9 27·5    |       | 19 | 9 43·0                            | 6 46·8    |
|       | 24 | 13 41·2                               | 15 14·5   |       | 20 | 5 24·1                            | 12 34·0   |
|       | 25 | 9 22·1                                | 11 5·8    |       | 21 | 10 55·8                           | 8 25·4    |
|       | 26 | 5 3·1                                 | 6 57·1    |       | 22 | 6 36·8                            | 14 12·6   |
|       |    | 14 53·5                               | 16 52·8   |       | 23 | 12 8·5                            | 10 4·0    |
|       | 27 | 10 34·5                               | 12 44·1   |       | 24 | 7 49·6                            | 5 55·5    |
|       | 28 | 15·5                                  | 8 35·4    |       | 25 | 13 21·2                           | 11 42·7   |

|         |  | I.        | II.                                            |          |  | I.        | II.       |
|---------|--|-----------|------------------------------------------------|----------|--|-----------|-----------|
|         |  | (877° 90) | (870° 27)                                      |          |  | (877° 90) | (870° 27) |
| 1889.   |  | h m       | h m                                            | 1889.    |  | h m       | h m       |
| Aug. 26 |  | 9 2.3     | 7 34.1                                         | Sept. 24 |  | 11 54.0   | 6 37.6    |
| 27      |  | 14 34.0   | 13 21.3                                        | 25       |  | 7 35.2    | 12 25.0   |
| 28      |  | 10 15.1   | 9 12.8                                         | 26       |  | 3 16.4    | 8 16.6    |
| 29      |  | 5 56.2    | 5 4.3                                          | 27       |  | 8 48.3    | 4 8.2     |
|         |  | 15 46.8   | 15 0.0                                         | 28       |  | 4 29.5    | 9 55.6    |
| 30      |  | 11 27.9   | 10 51.5                                        | 29       |  | 10 1.4    | 5 47.2    |
| 31      |  | 7 9.1     | 6 43.0                                         | 30       |  | 5 42.6    | 11 34.6   |
| Sept. 1 |  | 12 40.8   | 12 30.2                                        | Oct. 1   |  | 11 14.5   | 7 26.2    |
| 2       |  | 8 21.9    | 8 21.7                                         | 2        |  | 6 55.7    | 13 13.6   |
| 3       |  | 4 3.1     | 4 13.2                                         | 3        |  | 12 27.6   | 9 5.2     |
|         |  | 13 53.6   | 14 9.0                                         | 4        |  | 8 8.9     | 4 56.8    |
| 4       |  | 9 39      | Middle of<br>fourth eclipse of <i>Sat. IV.</i> | 5        |  | 3 50.1    | 10 44.2   |
|         |  |           |                                                | 6        |  | 9 22.0    | 6 35.9    |
| 4       |  | 9 34.8    | 10 0.5                                         | 7        |  | 5 3.3     | 12 23.3   |
| 5       |  | 5 15.9    | 5 52.0                                         | 8        |  | 10 35.2   | 8 14.9    |
|         |  | 15 6.5    | 15 47.7                                        | 9        |  | 6 16.4    | 4 6.5     |
| 6       |  | 10 47.7   | 11 39.3                                        | 10       |  | 11 48.3   | 9 54.0    |
| 7       |  | 6 28.8    | 7 30.8                                         | 11       |  | 7 29.6    | 5 45.6    |
| 8       |  | 12 0.6    | 13 18.1                                        | 12       |  | 3 10.9    | 11 33.1   |
| 9       |  | 7 41.7    | 9 9.6                                          | 13       |  | 8 42.8    | 7 24.7    |
| 10      |  | 3 22.9    | 5 1.1                                          | 14       |  | 4 24.1    | 3 16.3    |
|         |  | 13 13.5   | 14 56.9                                        |          |  | 14 14.8   | 13 12.2   |
| 11      |  | 8 54.7    | 10 48.4                                        | 15       |  | 9 56.0    | 9 3.7     |
| 12      |  | 4 35.9    | 6 40.0                                         | 16       |  | 5 37.3    | 4 55.4    |
| 13      |  | 10 7.6    | 12 27.3                                        | 17       |  | 11 9.2    | 10 42.8   |
| 14      |  | 5 48.8    | 8 18.8                                         | 18       |  | 6 50.5    | 6 34.6    |
| 15      |  | 11 20.6   | 14 6.1                                         | 19       |  | 12 22.5   | 12 22.0   |
| 16      |  | 7 1.8     | 9 57.7                                         | 20       |  | 8 3.8     | 8 13.7    |
| 17      |  | 12 33.6   | 5 49.3                                         | 21       |  | 3 45.0    | 4 5.4     |
| 18      |  | 8 14.8    | 11 36.6                                        |          |  | 13 35.7   | 14 1.2    |
| 19      |  | 3 56.0    | 7 28.2                                         | 22       |  | 9 17.0    | 9 52.8    |
| 20      |  | 9 27.9    | 13 15.5                                        | 23       |  | 4 58.3    | 5 44.5    |
| 21      |  | 5 9.1     | 9 7.1                                          | 24       |  | 10 30.2   | 11 32.0   |
| 22      |  | 10 40.9   | 4 58.7                                         | 25       |  | 6 11.5    | 7 23.6    |
| 23      |  | 6 22.1    | 10 46.0                                        |          |  |           |           |

In order to reduce the longitudes of system I of the three preceding ephemerides to those adopted in the present ephemeris, the following corrections, duly interpolated, must be applied :

|               |       |              |        |              |       |
|---------------|-------|--------------|--------|--------------|-------|
| 1885, Nov. 14 | +58°0 | 1887, Jan. 8 | +159°2 | 1888, Jan. 3 | +33°2 |
| 1886, Jan. 13 | +28°0 | Mar. 9       | 138°2  | Mar. 3       | +12°2 |
| Mar. 14       | -2°0  | May 8        | 117°2  | May 2        | -8°8  |
| May 13        | -32°0 | July 7       | 96°2   | July 1       | -29°8 |
| July 12       | -62°0 | Sept. 5      | +75°2  | Aug. 30      | -50°8 |

The passages over the middle of the illuminated disc observed by Mr. A. S. Williams, and one, observed 1887, July 16, by Mr. Denning, give the following longitudes of the two equatorial spots according to system I of the present ephemeris :

| G.M.T.  |    |    |      | Long. | Long.   | G.M.T.  |    |      |      | Long. | Long. |
|---------|----|----|------|-------|---------|---------|----|------|------|-------|-------|
| 1887.   | h  | m  |      | °     | °       | 1888.   | h  | m    |      | °     | °     |
| Mar. 16 | 13 | 34 | W.   | ...   | 177°6   | May 13  | 14 | 18   | W.   | ...   | 167°6 |
|         | 18 | 14 | 45   | "     | 176°9   |         | 15 | 11   | 9    | 8°4   |       |
|         | 23 | 13 | 0    | "     | 183°0   |         | 19 | 13   | 30.5 | 6°8   |       |
| July 16 | 8  | 12 | D.   | ...   | 169°2   |         | 20 | 13   | 50   | ...   | 176°7 |
| 1888.   |    |    |      |       |         |         | 21 | 14   | 44   | 7°7   |       |
| Mar. 1  | 14 | 57 | W.   | ...   | 177°7   |         | 22 | 10   | 22   | 5°9   |       |
|         | 25 | 14 | 50   | 4°2   |         |         | 23 | 10   | 32   | ...   | 170°1 |
| Apr. 1  | 14 | 9  |      | 5°1   |         |         | 24 | 11   | 30   | 3°5   |       |
|         | 3  | 15 | 21   | 5°0   |         |         | 25 | 11   | 37   | ...   | 165°8 |
|         | 4  | 15 | 31   | ...   | 169°1   | June 1  | 11 | 18   | ...  | 180°3 |       |
|         | 6  | 12 | 13   | 4°4   |         |         | 2  | 12   | 7    | 8°2   |       |
|         | 8  | 13 | 20   | 1°2   |         |         | 3  | 12   | 44   | ...   | 188°7 |
|         | 14 | 11 | 40   | ...   | 168°3   |         | 10 | 11   | 59.5 | ...   | 187°5 |
|         | 20 | 15 | 26   | ...   | 174°2   |         | 14 | 9    | 27   | 6°4   |       |
|         | 26 | 14 | 19   | 1°6   |         |         | 16 | 10   | 29   | 0°1   |       |
|         | 29 | 15 | 55 ± | ...   | 174°2 ± |         | 17 | 11   | 8    | ...   | 181°9 |
| May 1   | 12 | 26 |      | 2°8   |         |         | 22 | 9    | 15   | ...   | 182°7 |
|         | 3  | 13 | 44.5 | 6°8   |         |         | 30 | 9    | 10   | 3°0   |       |
|         | 5  | 14 | 55   | 5°8   |         | July 1  | 9  | 49.5 | ...  | 185°0 |       |
|         | 10 | 13 | 1°5  | 6°8   |         |         | 18 | 10   | 12   | 2°5   |       |
|         | 11 | 13 | 9    | ...   | 169°4   |         | 19 | 10   | 46   | ...   | 181°1 |
|         | 12 | 14 | 13   | 6°5   |         | Aug. 25 | 8  | 19.5 | ...  | 169°6 |       |
|         | 13 | 9  | 52   | 5°4   |         |         |    |      |      |       |       |

*Note on the Values of the Constants for the new Dearborn Observatory.*  
By Lieutenant-General Tennant.

Since the proofs were passed I have received a communication as to the place of this Observatory from Professor Hough, the director, giving the following results:

| Longitude from Greenwich. |               |  |  | Corr. to | Lat.    | tan $\phi'$ . | log A. | log D. | log P. |
|---------------------------|---------------|--|--|----------|---------|---------------|--------|--------|--------|
| Time.                     | Parts of day. |  |  | S.T.M.N. |         |               |        |        |        |
| h m s                     | d             |  |  | s        | ° '     |               |        |        |        |
| - 5 50 42                 | - 0.243542    |  |  | + 57.61  | + 42 03 | 9.9522        | 9.6388 | 0.7671 | 0.9428 |

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*Errata in Professor Holden's Observations of Nebulæ, Monthly Notices,*  
*Vol. XLVIII. No. 9.*

Figure at bottom of p. 386—Insert B in the middle of the triangle which has *d*, *c* and 14 for vertices.

Page 390, line 4 from top, *dele* "blue."

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